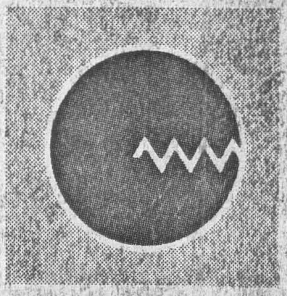
FIELD Tektronix INFORMATION PUBLICATION

USING YOUR TYPE 535 OR TYPE 545 OSCILLOSCOPE



including . . . . .

TYPICAL APPLICATIONS

USING YOUR
TYPE 535 OR TYPE 545
OSCILLOSCOPE

INCLUDING
TYPICAL APPLICATIONS

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Request Form FIP-1

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Note 1

In these instructions, **BOLD-FACED CAPITALS** indicate front-panel controls or control positions, or front-panel connectors.

Note 2

Note front-panel colors on your instrument. Black lettering goes with black knobs; red lettering goes with red knobs.

Note 3

Before you use these instructions with an individual oscilloscope, first find out which one of the following categories includes your instrument.

Category 1: If the red **TRIGGERING MODE** switch, in the upper right-hand corner of the front panel, has a position marked **AC AUTO.** (rather than **AUTOMATIC**), your instrument is in Category 1.

Category 2: If the red **TRIGGERING MODE** switch, in the upper right-hand corner of the front panel, has a position marked **AUTOMATIC** (rather than **AC AUTO.**), note whether the red Main Sweep **STABILITY** control (located to the left of the **TRIGGERING MODE** switch) has a **PRESET** position, marked either on the knob or on the panel adjacent to the knob. If it does **not**, your instrument is in Category 2.

Category 3: If the red **TRIGGERING MODE** switch, in the upper right-hand corner of the front panel, has a position marked **AUTOMATIC** (rather than **AC AUTO.**), and if the Main Sweep **STABILITY** control (located to the left of the **TRIGGERING MODE** switch) has a **PRESET** position, marked either on the knob or on the panel adjacent to the knob, your instrument is in Category 3.

PART 1

GETTING ACQUAINTED

WITH YOUR TYPE 535
OR TYPE 545 OSCILLOSCOPE

In order to help you begin using your new oscilloscope as soon as possible, we have outlined in this section some of the more frequently encountered oscilloscope operations.

The oscilloscope provides us with a means of actually looking at some voltage waveform we are interested in. To accomplish this, we feed this waveform into the INPUT or CHANNEL connector of the plug-in preamplifier. In most cases, we use the oscilloscope so that the display on the screen shows how the voltage of this waveform changes with time. For get-acquainted purposes, or to check the operation of the oscilloscope, we shall look at the square-wave signal generated by the CALIBRATOR which is built into the oscilloscope. For these purposes, we suggest the use of a Type 53/54A, Type 53/54B, Type 53/54K or Type 53/54L Plug-In Preamplifier. Operating instructions for the plug-in preamplifier are given in the Instruction Manual for the preamplifier.

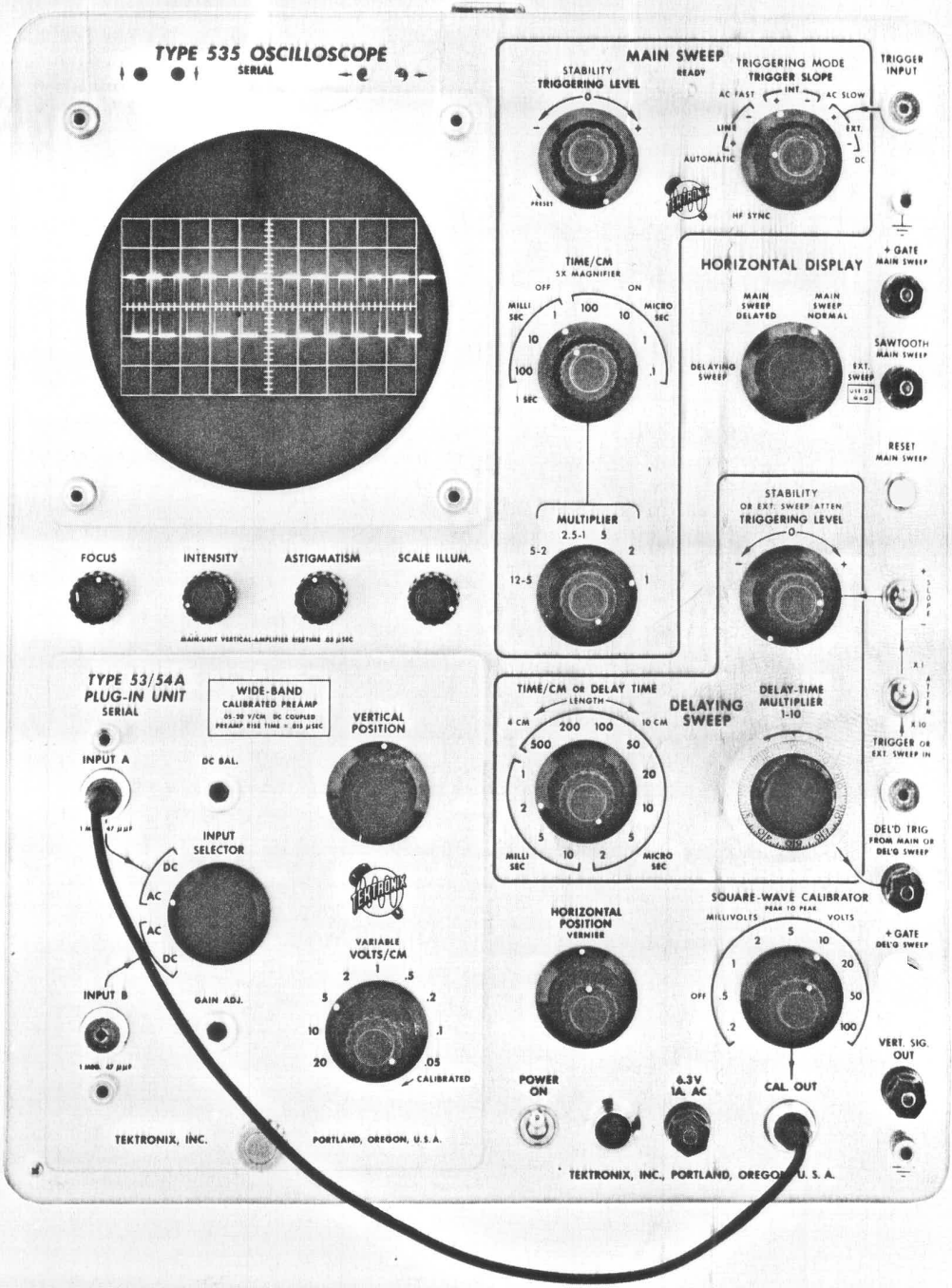
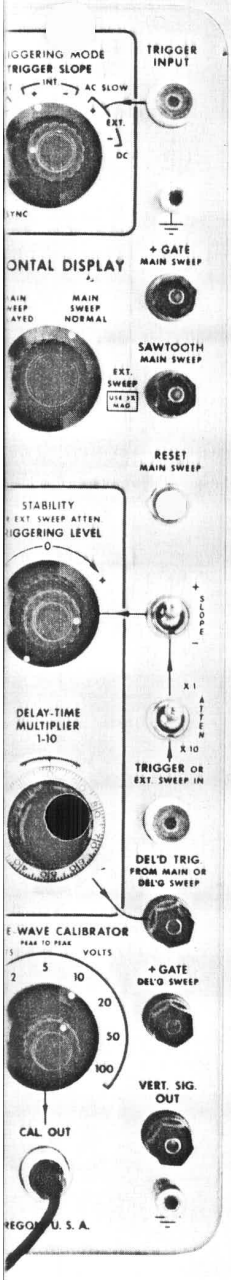


Fig. 1. Triggering in the Automatic mode.



Initial Control Settings

Set the controls as follows (see Fig. 1):

HORIZONTAL DISPLAY	MAIN SWEEP NORMAL
5X MAGNIFIER	OFF

Main Sweep controls:

TRIGGERING MODE	AUTOMATIC*
TRIGGER SLOPE	+ INT.
STABILITY	full right (clockwise)†
TRIGGERING LEVEL	full right (clockwise) or full left (counterclockwise)
TIME/CM	1 MILLISEC
MULTIPLIER	1

Plug-in preamplifier controls:

INPUT SELECTOR or AC-DC switch	AC (INPUT A if available)
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Other controls:

FOCUS	centered
INTENSITY	full left
ASTIGMATISM	centered
HORIZONTAL POSITION	centered
SQUARE-WAVE CALIBRATOR	10 VOLTS
POWER	ON

*On oscilloscopes in Category 1 (page 1), set the TRIGGERING MODE switch to AC AUTO.

†On oscilloscopes in Category 1, set the STABILITY control full right. In oscilloscopes in Categories 2 and 3, the STABILITY control is disabled when the TRIGGERING MODE switch is in the AUTOMATIC position.

Turn the **INTENSITY** control to the right until a horizontal trace of useful brightness appears on the screen. Adjust the **FOCUS** and **ASTIGMATISM** controls for the sharpest trace. Connect a lead from the **CAL. OUT** connector to the **INPUT (A)** or **CHANNEL A** connector. (On oscilloscopes in Category 1, turn the Main Sweep **STABILITY** control slowly left until the trace is stable.) The display on the screen should now be a square wave. Slightly readjust the **FOCUS, INTENSITY** and **ASTIGMATISM** controls so that the display has the best sharpness and suitable brightness as shown in Fig. 2. Center the display on the graticule by means of the **VERTICAL POSITION** and **HORIZONTAL POSITION** controls.

Triggering In The Automatic Mode

The ac waveform you have been looking at is a **periodic** signal—that is, the same waveform recurs at regular intervals. We got a stable (stationary) display of this waveform by setting the oscilloscope controls so that each horizontal sweep of the spot across the screen started at a given point on the waveform we were looking at. These settings were given in the table at left. For present purposes, the starting of each horizontal sweep across the screen can be called "triggering" the sweep. As in the procedure above, this can be accomplished with a minimum of adjustment by setting the red **TRIGGERING MODE** knob to the **AUTOMATIC** position. That is, we used the **AUTOMATIC** mode of triggering.

Because of its simplicity of operation, the **AUTOMATIC** (or **AC AUTO.**) mode is one of the most useful triggering modes. In particular, you don't have to adjust the **TRIGGERING LEVEL** control when you use this mode. Further, in the case of instruments in Categories 2 and 3, you don't have to adjust the Main Sweep **STABILITY** control when you use the **AUTOMATIC** mode.

Now remove the calibrator-signal lead from the **INPUT** or **CHANNEL** connector. Notice that the display now consists of a straight horizontal trace. This trace serves as a desirable reference trace when you are testing equipment by moving a probe or other input connection from point to point in the equipment being tested. This reference trace in the absence of a triggering signal is not obtained when you are using triggering modes other than **AUTOMATIC**.

Now replace the calibrator-signal connection to the **INPUT** or **CHANNEL** connector.

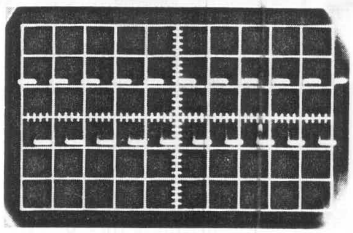


Fig. 2. Display of Calibrator waveform.

Effect of the Vertical Position Control

Turn the **VERTICAL POSITION** control back and forth, and notice that this raises and lowers the display on the screen. Note especially that if you position the display off the graticule in either direction, one of the beam-position indicator lamps, located above the graticule, will indicate in which direction the display is positioned off the screen. This tells you which way to turn the **VERTICAL POSITION** control in order to get the trace back on the screen.

Now reset the **VERTICAL POSITION** control to return the display to the center of the screen.

Effect of the AC-DC switch

Set the AC-DC switch (or **INPUT SELECTOR** switch) on the plug-in preamplifier to **DC**. Notice the vertical shift in the position of the trace. This shift occurs because the output waveform from the **CALIBRATOR** has both an ac (square-wave) component and a dc component. When the **AC-DC** switch is in the **AC** position, the effect of the dc component is excluded from the display. When this switch is in the **DC** position, the display indicates both the ac and the dc components of the waveform being observed. The dc component of the waveform causes the entire display to rise or fall on the screen.

Now reset the switch to **AC**.

Effects of the Volts/cm Controls

Turn the **VOLTS/CM** knob successively to positions both to the right and to the left of the **5** position. Notice that when you set the **VOLTS/CM** control to higher-numbered positions, the amount of vertical deflection produced on the screen by the **CALIBRATOR** waveform is reduced, and vice versa.

Reset the **VOLTS/CM** knob to the **5** position.

Turn the **VARIABLE VOLTS/CM** knob to the left. Notice that this reduces the amount of vertical deflection produced on the screen by the **CALIBRATOR** waveform. Now reset the **VARIABLE** control to the **CALIBRATED** position.

The above operations point up the fact that the **VOLTS/CM** switch and the **VARIABLE** knob provide control of the amount of deflection which results from feeding a waveform having a given peak-to-peak voltage into the **INPUT** or **CHANNEL** connector.

Effect of the Horizontal Position Control

Turn the black **HORIZONTAL POSITION** control back and forth, and notice that the display moves to the left and to the right on the screen. Note especially that if you position the knob to the extreme right, one of the beam-position indicator lamps (located above the graticule) will indicate that the display is positioned off the center towards the right. This tells you which way to turn the **HORIZONTAL POSITION** control in order to get the trace back on the screen.

Turn the red **VERNIER** control back and forth, and note that this gives you a fine control of the horizontal position of the trace.

Now set the **HORIZONTAL POSITION** and **VERNIER** controls so that the trace is centered horizontally.

Effect of the Time/cm and Multiplier Controls

Turn the black Main Sweep **TIME/CM** knob successively to positions both to the right and to the left of the **1 MILLISEC** position. Notice that the display expands or contracts horizontally as you turn this switch.

Reset the **TIME/CM** switch to the **1 MILLISEC** position.

Turn the black **MULTIPLIER** knob to the **2** position. Note that the number of cycles displayed across the screen is doubled. Then turn the black **MULTIPLIER** knob to **5**. This gives five times the number of cycles as were displayed across the screen when the **MULTIPLIER** knob was in the **1** position.

Now set the black **MULTIPLIER** knob to the **2.5-1** position. Note that you now have continuously variable control over the number of cycles displayed, by means of the red **MULTIPLIER** knob. Similarly for the 5-2 and the 12-5 positions.

Now reset the black **MULTIPLIER** knob to 1.

The above operations point up the fact that the Main Sweep **TIME/CM** switch and the **MULTIPLIER** control provide control of the number of cycles of the display which appear on the screen when a waveform having a fixed repetition rate is displayed.

Effect of the 5X Magnifier

Turn the red **5X MAGNIFIER** knob to **ON**. Notice the resulting horizontal expansion of

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the trace. Turn this switch from **OFF** to **ON** and back several times. Observe that the portion of the waveform that occupies the middle two divisions of the graticule length when the switch is **OFF** is expanded to occupy the entire graticule length when the switch is **ON**.

With the **5X MAGNIFIER** turned **ON**, turn the **HORIZONTAL POSITION** control through its range and notice that the display has been expanded beyond the limits of the graticule.

Now reset the **5X MAGNIFIER** switch to **OFF**. With the **HORIZONTAL POSITION** control, return the display to the horizontal center of the graticule.

Effect of the Trigger Slope Control

Set the Main Sweep **TIME/CM** control to 100 **MICROSEC**. Carefully observe that part of the display which appears at the left-hand end of the graticule. Notice that the trace begins during the rising portion of the square wave. That is, the sweep is **triggered** at a time when the **slope** of the wave is positive. (See Fig. 3.) This is because the **TRIGGER SLOPE** knob is set to + **INT.**, rather than to — **INT.**

Now turn the **TRIGGER SLOPE** to — **INT.** Observe that the display appears to turn upside-down, so that it now begins during a falling portion of the square wave, at the left-hand end of the graticule. That is, the sweep is **triggered** at a time when the **slope** of the wave is negative.

Note that one of the purposes of the **TRIGGER SLOPE** knob is to provide control over whether the sweep is triggered when the slope of the waveform is positive, or whether it is triggered when the slope of the waveform is negative, as just described. Turn the **TRIGGER SLOPE** knob back and forth between + **INT.** and — **INT.** several times, observing the left-hand end of the display carefully to see how the sweep starts on either a rising or falling part of the waveform.

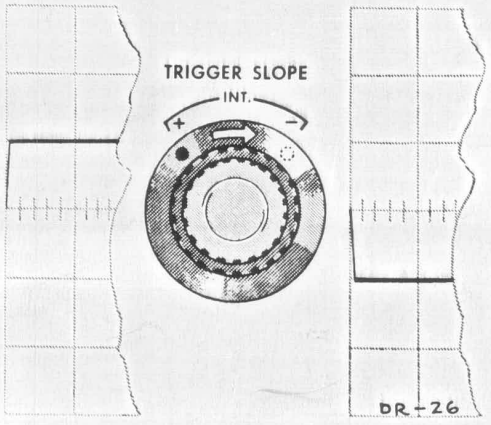


Fig. 3. Effect of the Trigger Slope control.

Further use of the **TRIGGER SLOPE** knob will be described later in the "Operating Instructions" section, under the heading "Horizontal Deflection System."

Now return the **TRIGGER SLOPE** knob to the + **INT.** position.

The AC Slow Triggering Mode; Effect of the Triggering Level Control

After completing the previous operations, see that the following controls are set as indicated (see Fig. 4):

TRIGGERING MODE	**AC SLOW**
TRIGGER SLOPE	+ **INT.**
Main Sweep **STABILITY**	**PRESET** (turn left until internal switch is actuated)*
Main Sweep **TRIGGERING LEVEL**	full right (clockwise) or full left (counterclockwise)

***In instruments in Categories 1 and 2, turn the STABILITY control full right after completing the other settings in this list. Then turn the STABILITY control slowly left until the trace disappears, then two or three degrees farther left.**

Slowly turn the Main Sweep **TRIGGERING LEVEL** control toward the 0 position until the trace reappears; adjust this control for a stable display of the **CALIBRATOR** waveform. We say that triggering is now being effected in the **AC SLOW** mode.

Remove the **CALIBRATOR** lead from the **INPUT** or **CHANNEL** connector. Note that this causes the trace to disappear. That is, the reference trace provided in the **AUTOMATIC** mode is not available in the **AC SLOW** mode. Now reconnect the **CALIBRATOR** lead to the **INPUT** connector so that the trace reappears.

Next, slowly turn the Main Sweep **TRIGGERING LEVEL** control several times back and forth throughout its range from —, through 0, to +. Carefully observe the left-hand end of the display while you do this. Note that there is a certain part of the range of this control that provides a display; settings too far toward the — or the + marks on the panel result in no display.

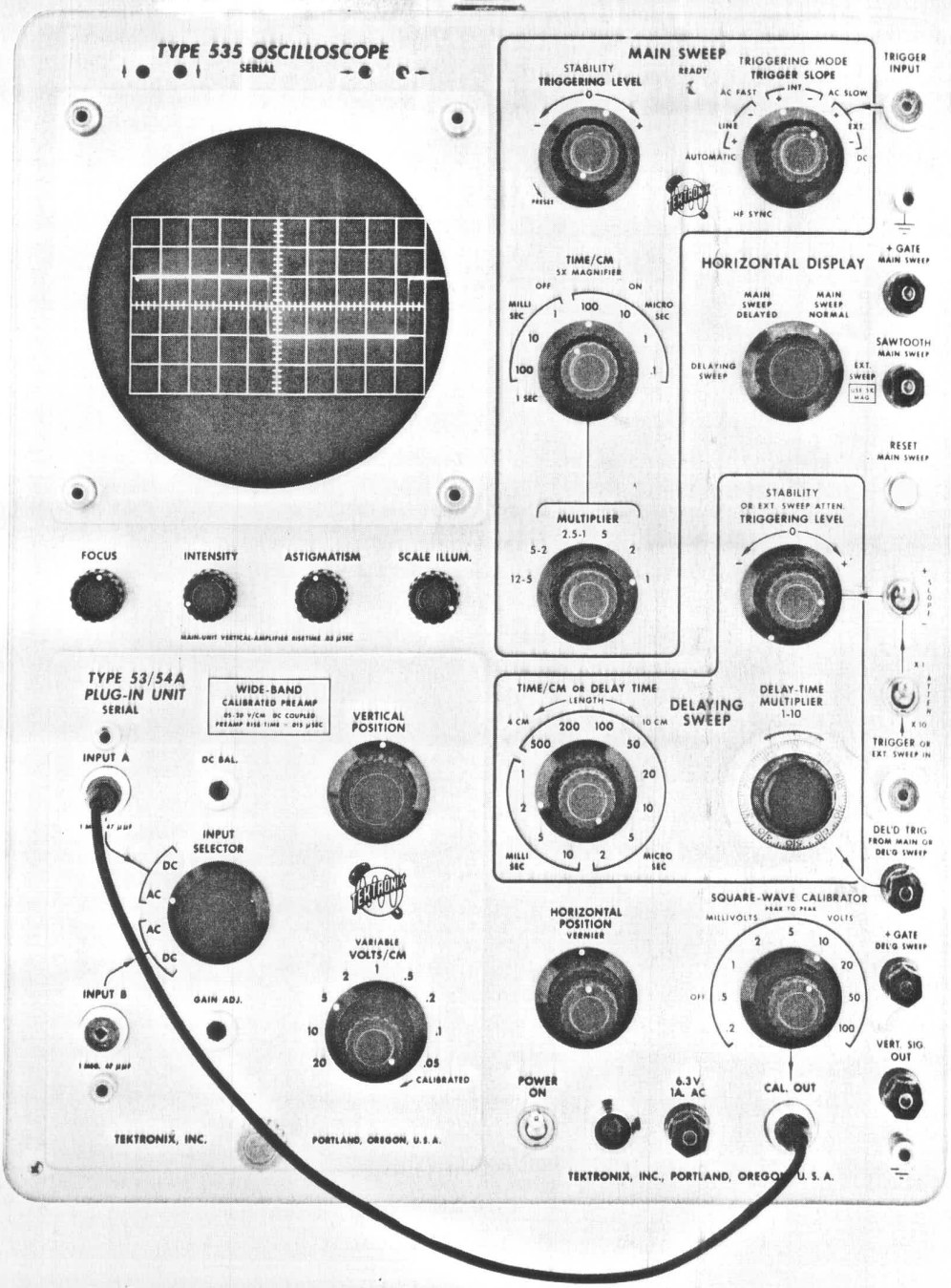
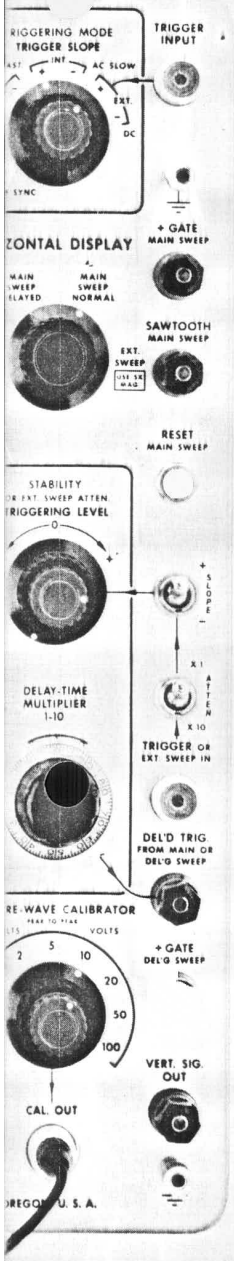


Fig. 4. Triggering in the AC Slow mode.



If the **INTENSITY** control is sufficiently advanced, you can also observe that in that part of the range of the Main Sweep **TRIGGERING LEVEL** control where you get a display, the **TRIGGERING LEVEL** control determines the height or "level" of the point on the waveform where the display starts. If you set the Main Sweep **TRIGGERING LEVEL** control more toward the + part of its range, the display starts on the higher part of the waveform. If you set the **TRIGGERING LEVEL** control more toward the — part of its range, the display starts on the lower part of the waveform (see Fig. 5). (Incidentally, you might even get the display to start on the lower "flat" portion of the waveform, because this part of the waveform as generated by the calibrator has a slight upward slope.) Since the **TRIGGER SLOPE** knob is set to **+INT.**, the display in each case starts on the rising part of the waveform (where its slope is positive).

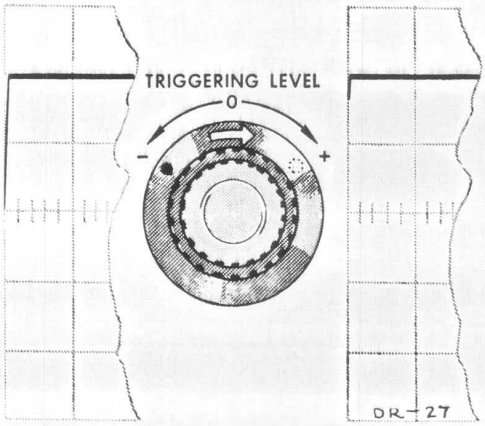


Fig. 5. Effects of the Triggering Level control when the Trigger Slope control is in a + position.

Now reduce the **CALIBRATOR** control setting to **5 VOLTS.** Repeat the observations in the preceding paragraph. Note that the vertical deflection you observe on the display is reduced to one-half its former value. Particularly, notice also that the range over which the Main Sweep **TRIGGERING LEVEL** control is effective in producing a display is reduced. This reduction in effective range of the Main Sweep **TRIGGERING LEVEL** control is caused by the smaller triggering signal derived internally from the displayed waveform.

Now turn the **CALIBRATOR** control back to **10 VOLTS.**

Turn the **TRIGGER SLOPE** knob to **—INT.**, so that the waveform appears upside-down—that is, it starts on the falling part of the waveform (where the slope is negative). Repeat the observations of the previous paragraph, and note that you can still control the height of the point where the trace starts by means of the Main Sweep **TRIGGERING LEVEL** control (see Fig. 6). (You might even get the display to start on the upper "flat" portion of the waveform, because this part of the waveform as generated by the calibrator has a slight downward slope.)

Reset the black **TRIGGER SLOPE** knob to **+INT.** Now turn the **VERTICAL POSITION** control back and forth, so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a fixed setting of the Main Sweep **TRIGGERING LEVEL** control, the trace always starts at a given point on the waveform, regardless of the setting of the **VERTICAL POSITION** control.

These brief statements can be made to compare the **AC SLOW** and the **AUTOMATIC** modes of triggering:

1. It is necessary to adjust the Main Sweep **TRIGGERING LEVEL** control when you use the **AC SLOW** (or the **AC FAST**) mode of triggering, but not when you use the **AUTOMATIC** mode.

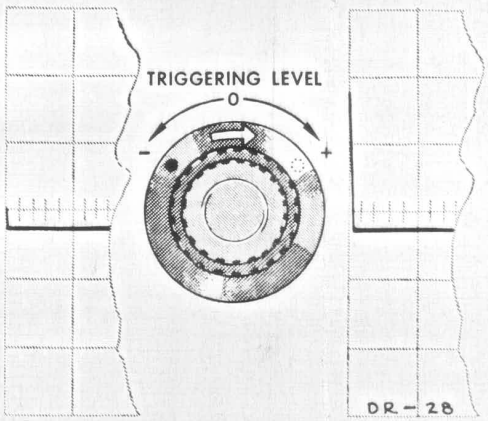


Fig. 6. Effects of the Triggering Level control when the Trigger Slope control is in a — position.

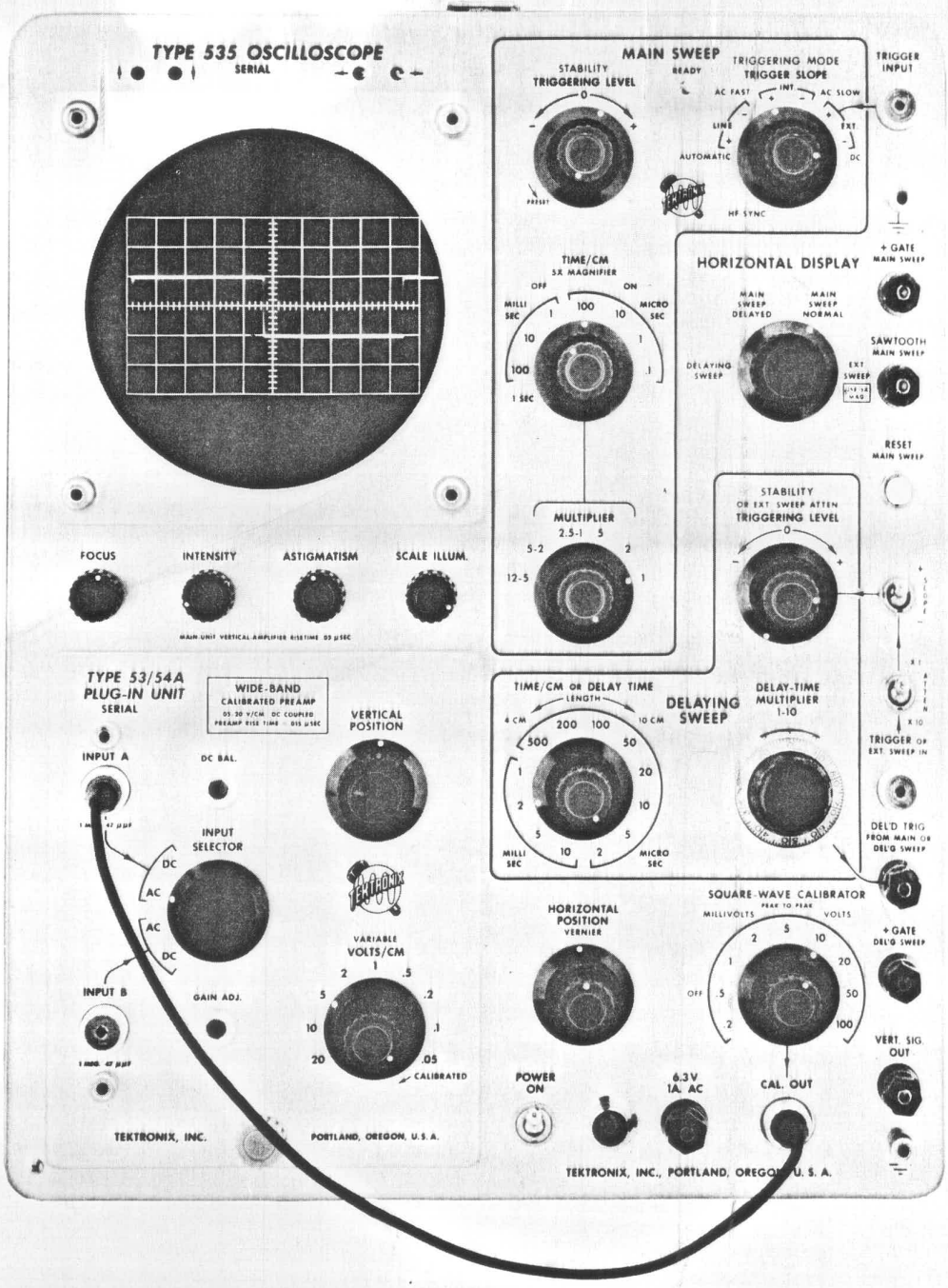
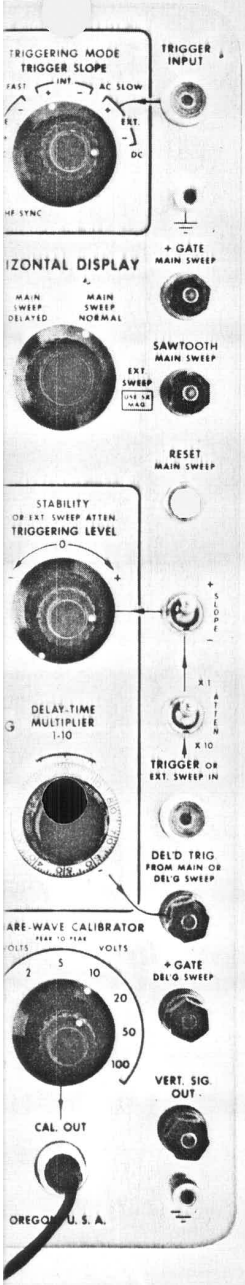


Fig. 7. Triggering in the DC mode.



2. When you use the **AUTOMATIC** mode, you get a horizontal reference trace on the screen, even when no input signal is used. This will be especially handy when you are testing equipment by moving the input connection from one point to another in the equipment. When you use the **AC SLOW** mode, no trace appears when there is no input signal.

3. In the **AC SLOW** mode, the **TRIGGERING LEVEL** control provides control of the height or "level" at which the trace starts on the waveform being observed. This is not true in the case of the **AUTOMATIC** mode.

4. The **AUTOMATIC** mode is useful when you are looking at periodic waveforms. The **AC SLOW** mode is useful for both periodic waveforms and for waveforms which occur only once or at ramdom intervals.

Note: For most uses, the **AC SLOW** mode is preferable to the **AC FAST** mode. Use of the **AC FAST** mode is described in the "Operating Instructions" section.

The DC Triggering Mode

After completing the previous operation, use the **VERTICAL POSITION** control to center the display vertically on the screen. Set the Main Sweep **TRIGGERING LEVEL** control for a stable display with the control located as close as possible to **0**.

Turn the **TRIGGERING MODE** switch to **DC** (see Fig. 7). If necessary, readjust the Main Sweep **TRIGGERING LEVEL** control for a stable display. You are now triggering the sweep in the DC mode.

Slowly turn the Main Sweep **TRIGGERING LEVEL** control several times back and forth throughout its range from —, through **0**, to +. Carefully observe the left-hand end of the display while you do this. Note that the results are very much like those you got when you used the **AC SLOW** mode.

Turn the **TRIGGER SLOPE** knob to **— INT.**, and repeat the above operation. Again note the results are similar to those you obtained when you used the **AC SLOW** mode. Return the **TRIGGER SLOPE** knob to **+ INT.**

Now turn the **VERTICAL POSITION** control back and forth, so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a given setting of the Main Sweep **TRIGGERING LEVEL** control, the trace starts at a given point on the graticule, regardless of the setting of the **VERTICAL POSITION** control (see Fig. 8). (If you position the trace too high or too low, so that the waveform does not include this starting point, the trace disappears.)

The four comments at the close of the section on the **AC** triggering mode apply also to triggering in the **DC** mode. The following statements can be made to compare the **DC** and **AC SLOW** modes of triggering:

1. When you use the **DC** mode, the trace always starts at a given point on the **graticule**, for a given Main Sweep **TRIGGERING LEVEL** setting (regardless of the **VERTICAL POSITION** setting). But when you use the **AC SLOW** mode, the trace always starts at a given point on the **waveform**, for a given Main Sweep **TRIGGERING LEVEL** setting (regardless of the **VERTICAL POSITION** setting).
2. The **DC** mode is especially useful for viewing waveforms which change slowly.

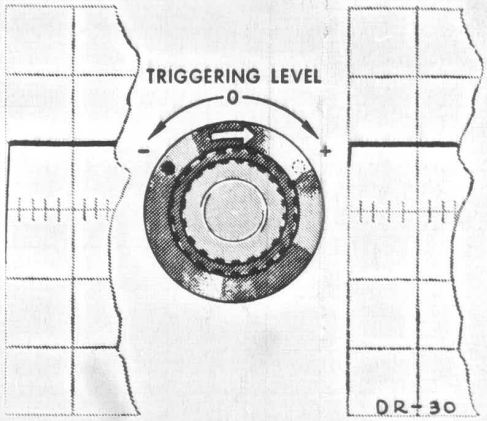


Fig. 8. Effects of the Triggering Level control when you use the DC mode.

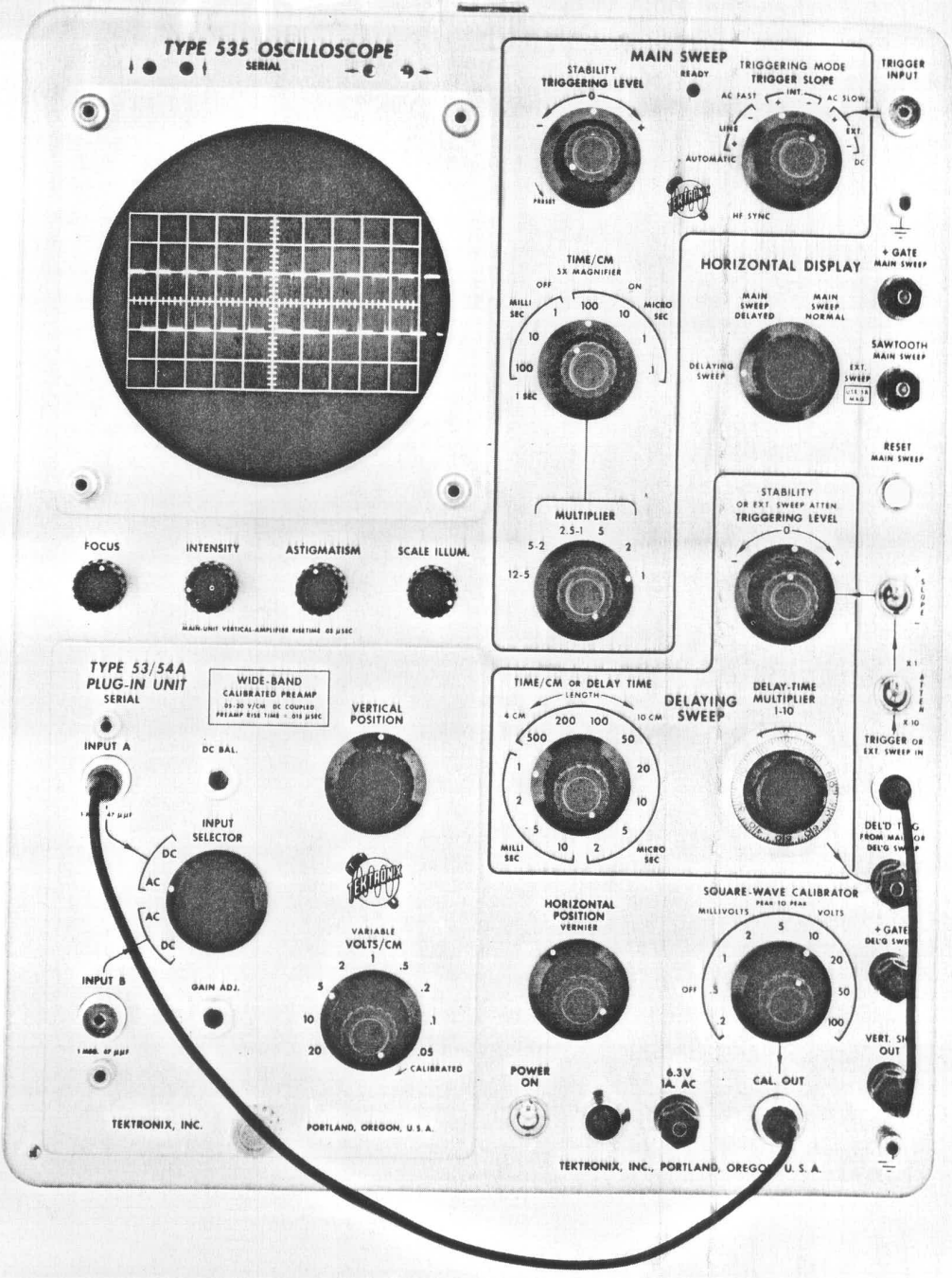
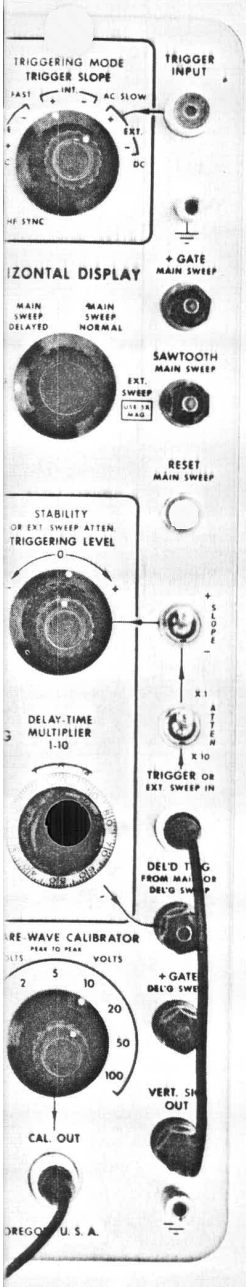


Fig. 9. Displaying a waveform by means of the Delaying Sweep.



Displaying a Waveform by Means of the Delaying Sweep

In this use, the Delaying Sweep, rather than the Main Sweep, is used for horizontal deflection. The Delaying Sweep replaces the Main Sweep for horizontal deflection when you switch the **HORIZONTAL DISPLAY** switch from **MAIN SWEEP NORMAL** to **DELAYING SWEEP**. Set the controls as follows (see Fig. 9):

HORIZONTAL DISPLAY	DELAYING SWEEP
5X MAGNIFIER	OFF

Main Sweep controls:

TRIGGERING MODE	AC SLOW or DC
STABILITY	full left*

Delaying Sweep controls:

SLOPE toggle	+
ATTEN. toggle	X1
STABILITY	full right
TRIGGERING LEVEL	full right or full left
TIME/CM OR DELAY TIME	1 MILLISEC
LENGTH	full right

Plug-in preamplifier controls:

INPUT SELECTOR or AC-DC SWITCH	AC (INPUT A if available)
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Other controls:

FOCUS	centered
INTENSITY	full left
ASTIGMATISM	centered
HORIZONTAL POSITION	centered
SQUARE-WAVE CALIBRATOR	10 VOLTS
POWER	ON

*On Instruments in Category 3, do not set this control so far that the PRESET switch that is a part of the control is actuated.

Turn the **INTENSITY** control to the right until a horizontal trace of useful brightness appears on the screen. Adjust the **FOCUS** and **ASTIGMATISM** controls for the sharpest trace. Connect a lead from the **CAL. OUT** connector to the **INPUT (A)** or **CHANNEL A** connector. Connect a lead from the **VERT. SIG. OUT** connector to the **TRIGGER OR EXT. SWEEP IN** connector. (To trigger the Delaying Sweep, you **always** have to connect the source of triggering signal to the **TRIGGER OR EXT. SWEEP IN** connector.) Turn the Delaying Sweep **STABILITY** control slowly toward the left until the trace disappears, then two or three degrees father left. Turn the Delaying Sweep **TRIGGERING LEVEL** control slowly toward the **0** position until a stable trace appears. Slightly readjust the **FOCUS, INTENSITY** and **ASTIGMATISM** controls so that the display has the best sharpness and suitable brightness. Center the display on the graticule by means of the **VERTICAL POSITION** and **HORIZONTAL POSITION** controls.

Operate the following controls, and note that they have the same effects that they had when you were using the Main Sweep: **VERTICAL POSITION; AC-DC** switch (or **AC** and **DC** positions of the **INPUT SELECTOR** switch); **VOLTS/CM; HORIZONTAL POSITION**, and **5X MAGNIFIER.** Now reset these controls to their original settings.

Turn the Delaying Sweep **TIME/CM OR DELAY TIME** knob successively to positions both to the right and to the left of the **1 MILLISEC** position. Notice that this provides control of the number of cycles displayed on the screen when a waveform having a fixed repetition rate is displayed by means of the Delaying Sweep. Reset the Delaying Sweep **TIME/CM OR DELAY TIME** knob to **1 MILLISEC.**

Switch the **SLOPE** toggle switch back and forth between + and —, and observe that this switch provides control over whether the display begins during the rise or during the fall of the displayed waveform. This occurs in a manner similar to that involved when you use the Main Sweep and switch the **TRIGGER SLOPE** control back and forth from **+INT.** to **—INT.**

Delayed Main Sweep

After completing the previous operation ("Displaying a waveform by means of the Delaying Sweep") leave the **TIME/CM OR DELAY TIME** control at **1 MILLISEC** and leave the other Delaying Sweep controls as they are. Set the following controls as indicated (see Fig. 10):

Main Sweep **STABILITY**	full right
Main Sweep **TIME/CM**	100 MICROSEC
MULTIPLIER	1
DELAY-TIME MULTIPLIER	6.50

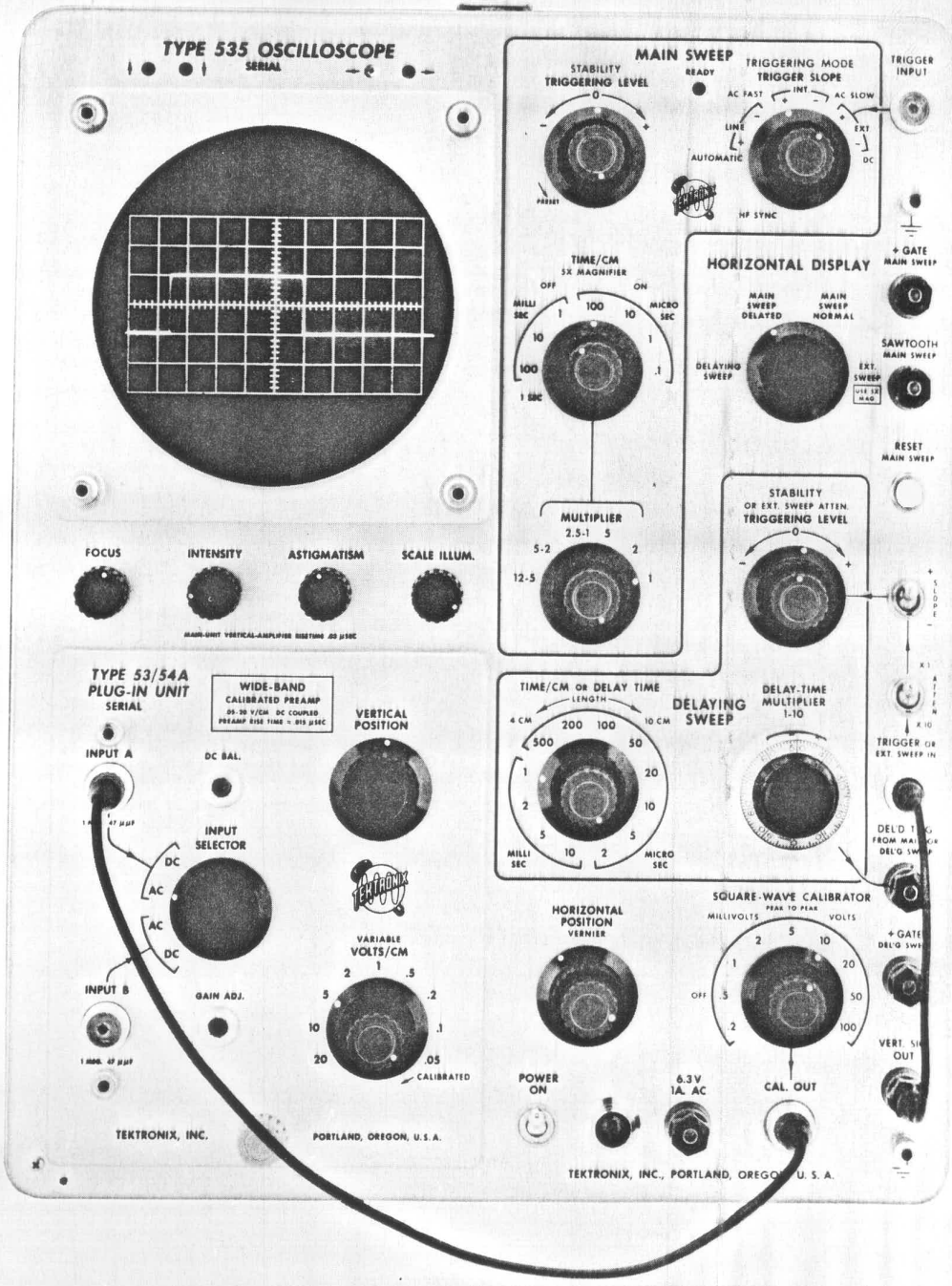
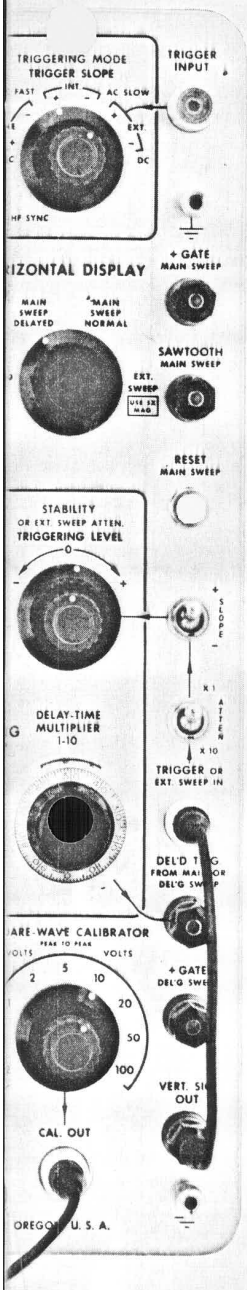


Fig. 10. Delayed Main Sweep.



That portion of the display between 6.5 centimeters and 7.5 centimeters along the graticule length should now be brighter than the rest of the display (don't have the **INTENSITY** control turned too far to the right, or you can't see this increased brightness).

Now turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED**. That portion of the original display that was brightened will now be expanded to fill the entire graticule length.

Now turn the **DELAY-TIME MULTIPLIER** slowly back and forth over the range from 1.00 to 10.00, meanwhile switching the **HORIZONTAL DISPLAY** control back and forth between **MAIN SWEEP DELAYED** and **DELAYING SWEEP**. Note that in each case the portion of the waveform that is brightened when the **HORIZONTAL DISPLAY** switch is in the **DELAYING SWEEP** position is displayed across the entire graticule length when the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP DELAYED** position. In this operation, when you turn the **HORIZONTAL DISPLAY** control to **MAIN SWEEP DELAYED**, you see the display as presented by the Main Sweep. Since you have set the Main Sweep **TIME/CM** control for a sweep rate 10 times as fast as the setting of the Delaying Sweep **TIME/CM OR DELAY TIME** control, the display is magnified 10 times as compared with the display presented by the Delaying Sweep (obtained when you set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP**).

Now set the Main Sweep **TIME/CM** control to **10 MICROSEC** (100 times as fast as the **1 MILLISEC** setting of the Delaying Sweep **TIME/CM OR DELAY TIME** control). Set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP**. Note that a much shorter portion (1 millimeter) of the display is brightened. Now turn the **DELAY-TIME MULTIPLIER** control slowly back and forth between 1.00 and 10.00, at the same time switching the **HORIZONTAL DISPLAY** switch back and forth between **DELAYING SWEEP** and **MAIN SWEEP DELAYED**, as in the paragraph above. Again note that the portion of the waveform that is brightened when the **HORIZONTAL DISPLAY** switch is in the **DELAYING SWEEP** position is displayed across the entire graticule length when the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP DELAYED** position. Here, the magnification is 100 times, since the Main Sweep **TIME/CM** control is set for a rate 100 times as fast as the setting of the Delaying Sweep **TIME/CM OR DELAY TIME CONTROL**.

Now reset the Main Sweep **TIME/CM** control to **100 MICROSEC**.

Delayed-and-Triggered Main Sweep

Set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP**. Set the Delaying Sweep **TIME/CM OR DELAY TIME** control to **1 MILLISEC**. Adjust the Delaying Sweep controls for a stable display of the **CALIBRATOR** signal as described previously under "Displaying a waveform by means of the Delaying Sweep." Set the **DELAY-TIME MULTIPLIER** control to **6.50**.

Set the Main Sweep **TIME/CM** control to **100 MICROSEC** and the **MULTIPLIER** to **1**. Turn the **TRIGGER SLOPE** switch to **+INT.**, and the **TRIGGERING MODE** switch to **AUTOMATIC**.*

The first **CALIBRATOR** square-wave cycle appearing to the right of the 6.5-centimeter point on the graticule length should appear brighter than the rest of the display. Now turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED**, and the part of the display that was brightened will now appear displayed across the entire graticule length (see Fig. 11).

Notice these differences between the present operation and the operation previously described— "Delayed Main Sweep":

1. In the Delayed Main Sweep operation, the portion of the display that is brightened when the **HORIZONTAL DISPLAY** switch is in the **DELAYING SWEEP** position begins at a point on the graticule length that is determined by the setting of the **DELAY-TIME MULTIPLIER**. This brightened portion will be displayed over the entire graticule length when you turn the **HORIZONTAL DISPLAY** switch to the **MAIN SWEEP DELAYED** position.
2. But in the present Delayed-and-triggered Main Sweep operation, the portion of the waveform that is brightened when the **HORIZONTAL DISPLAY** switch is in the **DELAYING SWEEP** position begins with the first leading edge of the waveform **after** that point on the graticule length determined by the **DELAY-TIME MULTIPLIER**

*On instruments in Category 1, set the **TRIGGERING MODE** switch to **AC AUTO.** and turn the Main Sweep **STABILITY** control full right. Then turn the Main Sweep **STABILITY** control slowly to the left until the brightened portion of the trace disappears. Next, turn this control slowly to the right until the brightened portion of the trace reappears, probably at a horizontal position different from that at which it originally appeared.

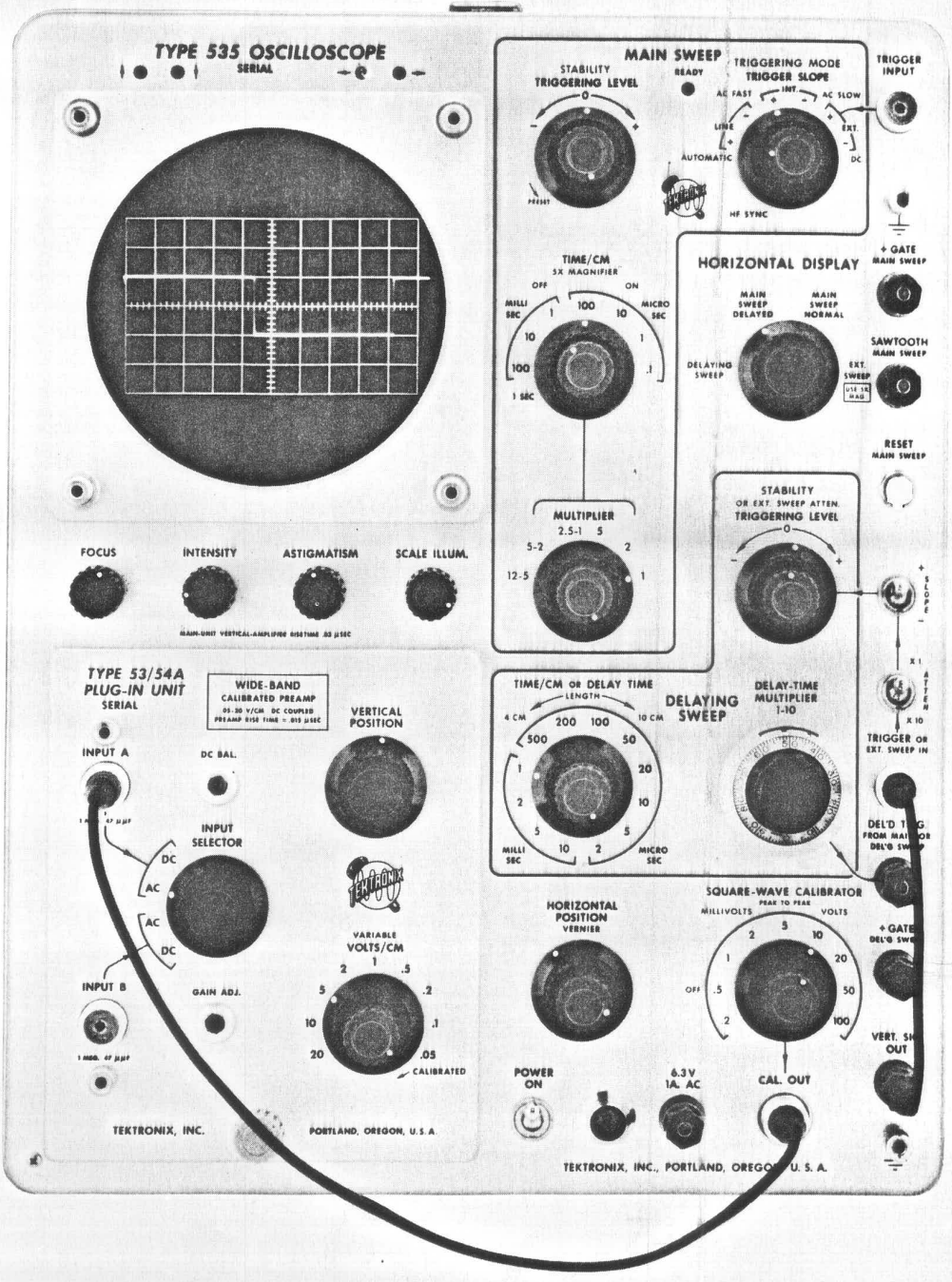
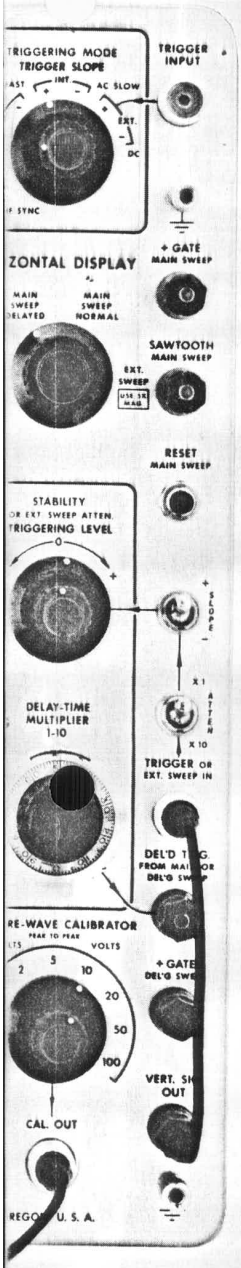


Fig. 11. Delayed-and-Triggered Main Sweep.



setting. This, too, is the portion that is displayed across the entire graticule length when you turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED.**

With the **HORIZONTAL DISPLAY** switch at **DELAYING SWEEP**, turn the **DELAY-TIME MULTIPLIER** control back and forth over its range from 1.00 to 10.00. Notice that the brightened portion of the waveform does not progress smoothly across the graticule as it did when you used the "Delayed Main Sweep" operation. Here, the brightened portion remains stationary until you turn the **DELAY-TIME MULTIPLIER** so far that the brightened portion starts at an earlier or later edge of the waveform.

At any time you can turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED** and view the brightened portion of the waveform expanded over the entire graticule length. (Here, the display will in all cases be identical, because all cycles of the calibrator square wave are similar.)

Now turn the Main Sweep **TRIGGER SLOPE** control to **—INT.** With the **HORIZONTAL DISPLAY** switch at **DELAYING SWEEP**, repeat the above operation with the **DELAY-TIME MULTIPLIER** control. Note that operation is similar to that you just obtained, except that now the brightened portion of the waveform starts on a falling edge rather than on a leading edge of the waveform.

NOTE: Although the operations described here under " Delayed Main Sweep" and "Delayed-and-Triggered Main Sweep" make the Delaying Sweep function to provide a very versatile and accurate magnifier, there are other important applications of the Delaying Sweep. Some of these are discussed later under "Operating Instructions."

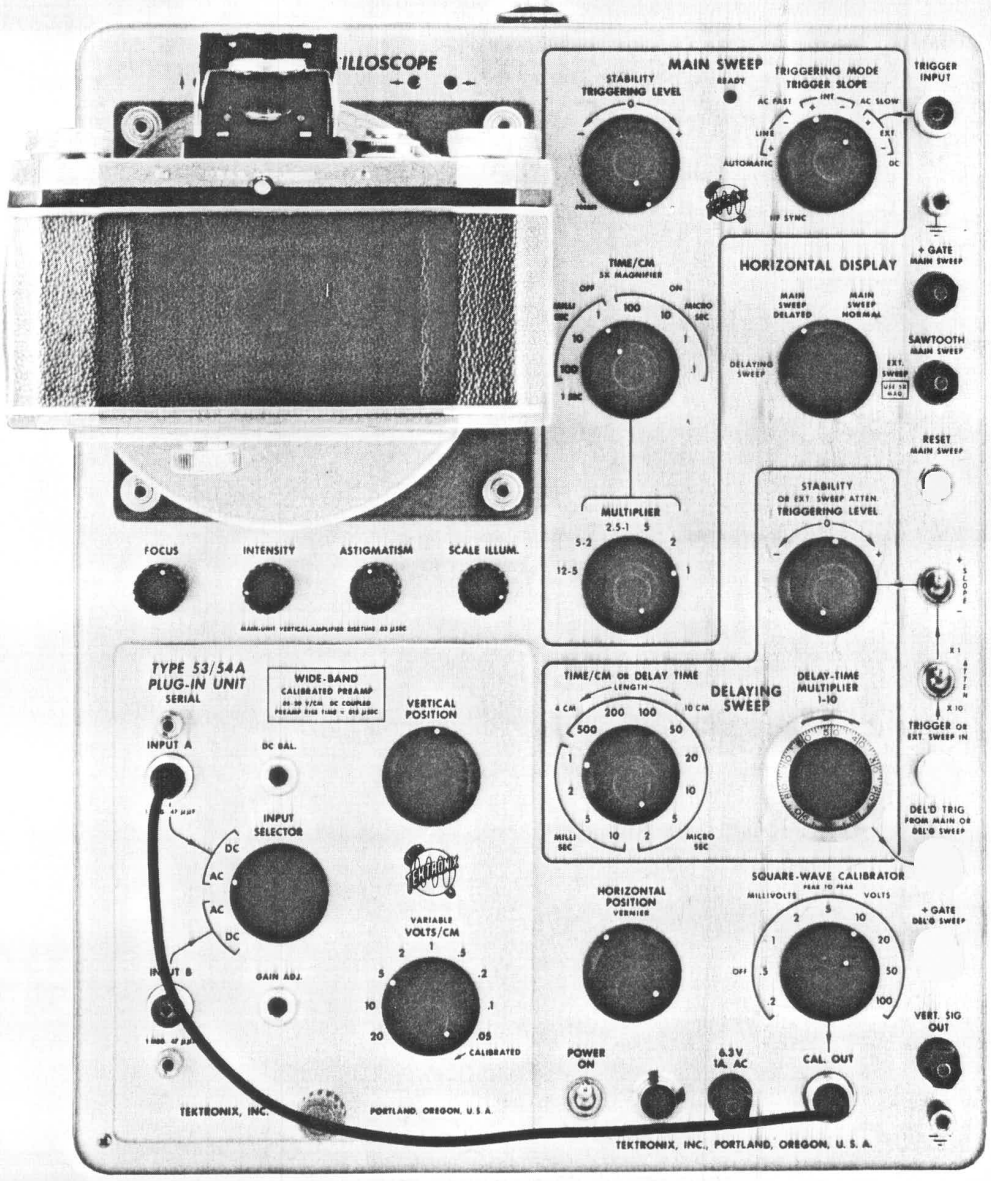
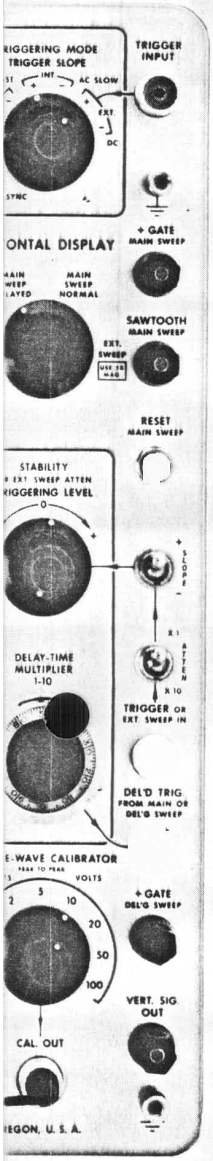


Fig. 12. Single Sweeps—Manual Operation.



Single Sweeps— Manual Operation

Set the front-panel controls as follows (see Fig. 12):

HORIZONTAL DISPLAY	MAIN SWEEP DELAYED*
Main Sweep controls:	
TRIGGERING MODE	AC SLOW
STABILITY	full right
TRIGGERING LEVEL	full right or full left
TIME/CM	1 MILLISEC
MULTIPLIER	1
Delaying Sweep controls:	
STABILITY	full left
Plug-in preamplifier controls:	
INPUT SELECTOR or AC-DC switch	AC (INPUT A if available)
VARIABLE	CALIBRATED
Other controls:	
SQUARE-WAVE CALIBRATOR	10 VOLTS
POWER	ON

*With operation as described here, no delaying action is applied to the sweep.

Connect a lead from the **CAL. OUT** connector to the **INPUT (A)** or **CHANNEL A** connector.

If you now operate the **RESET** push-button, you should get a single trace across the screen, displaying the **CALIBRATOR** square wave. Each time you operate the **RESET** push-button, you should get another single trace.

Single Sweeps— Triggered Operation

Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP NORMAL**, and turn the Delaying Sweep **STABILITY** control full left. Set the Main Sweep **TIME/CM** control to **1 MILLISEC** and the **MULTIPLIER** to 1. Connect a lead from the **CAL. OUT** connector to the **INPUT (A)** or **CHANNEL A** connector.

Get a stable display of the **CALIBRATOR** square wave according to the **AC SLOW** or **DC** mode as previously described.

Now turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED**.† The trace should disappear and the **READY** lamp should be extinguished. Remove the connecting lead from the **INPUT (A)** or **CHANNEL A** connector. Operate the **RESET** pushbutton. The **READY** lamp should now light.

Now touch the lead from the **CAL. OUT** connector momentarily to the **INPUT (A)** or **CHANNEL A** connector.

You should observe a single trace displaying the **CALIBRATOR** square wave. Following this, the **READY** lamp should be extinguished.

Now operate the **RESET** push-button again. The **READY** lamp should again light, and further application of the **CALIBRATOR** square wave to the **INPUT (A)** or the **CHANNEL A** connector should result in another single trace displaying the **CALIBRATOR** square wave. Repeat this operation several times.

†With operation as described here, no delaying action is applied to the sweep.

PART 2

OPERATING INSTRUCTIONS

INCLUDING

TYPICAL APPLICATIONS

This section includes the information in the previous section on "Getting Acquainted," in condensed form for easy reference. It also includes instructions on other applications of your oscilloscope.

HORIZONTAL-DEFLECTION SYSTEM

MAIN SWEEP

TRIGGERED OPERATION

For many uses of your oscilloscope, you will need to get a stable display of some recurrent waveform. To accomplish this, you can operate the oscilloscope so that each horizontal sweep of the spot across the screen starts at a given point on the waveform you are looking at. This is called "triggered" operation. For present purposes, then, we can refer to the starting of the horizontal sweep at the left-hand end of the graticule as "triggering" the sweep.

Triggered operation is also useful in looking at a waveform which occurs only once, or which occurs at random intervals.

For any of the above uses, the oscilloscope can alternatively be used in such a way that each horizontal sweep of the spot is triggered by some waveform other than the one you are observing, but which has a time relationship to the observed waveform.

The waveform used to start the horizontal sweep is called a "triggering signal" (whether it is the waveform being observed, or some other waveform). The following instructions tell you how to select the triggering signal. They also contain information on triggering according to various modes, depending upon the nature of the triggering signal.

How to Select the Triggering Signal

1. To trigger the Main Sweep from the waveform being observed, set the black **TRIGGER SLOPE** knob to **+INT.** or to **—INT.**
2. To trigger the sweep from the power-line wave, as in the case where you are observing a waveform which has a time relationship to the power-line wave, set the black **TRIGGER SLOPE** knob to **+LINE** or to **—LINE.**
3. To trigger the sweep from some externally derived waveform which has a time relationship to the observed waveform, connect the source of triggering waveform to the **TRIGGER INPUT** connector. Set the black **TRIGGER SLOPE** knob to **+EXT.** or to **—EXT.**

If you want the start of the display, at the left-hand end of the graticule, to occur at a time when the triggering signal is rising (has a positive slope), use the **+INT.**, the **+LINE** or the **+EXT.** position of the black **TRIGGER SLOPE** knob, as described above. If you want the start of the display to occur when the triggering signal is falling (has a negative slope), use the **—INT.**, the **—LINE** or the **—EXT.** position of the black **TRIGGER SLOPE** knob.

Automatic Mode

This is an especially useful triggering mode, providing automatic triggering from periodic signals in the range from about 60 cycles to 2 megacycles.

1. Select the desired triggering signal.
2. Set the Main Sweep **TIME/CM** switch for a sweep rate suited to the waveform being observed.
3. Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP NORMAL**, and set the red **TRIGGERING MODE** knob to **AUTOMATIC** (or **AC AUTO.**).*

*On instruments in Category 1, set the Main Sweep **STABILITY** control full right. Then turn it slowly left until the trace is stable.

AC Slow Mode

This mode is useful for triggering either from transients, or from periodic signals in the range from about 60 cycles to 5 megacycles.

1. Select the desired triggering signal.
2. Set the controls as follows:

HORIZONTAL DISPLAY	**MAIN SWEEP NORMAL**
TRIGGERING MODE	**AC SLOW**
Main Sweep **TRIGGERING LEVEL**	full right or full left
Main Sweep **STABILITY**	**PRESET**†

†On instruments in Categories 1 and 2, set this control full right. Then turn it slowly to the left until the trace disappears; then two or three degrees farther left.

3. Set the Main Sweep **TIME/CM** switch for a sweep rate suited to the waveform being observed.
4. Turn the Main Sweep **TRIGGERING LEVEL** control slowly toward the 0 position until the trace begins at the desired point on the waveform being observed.

DC Mode

In the DC mode, triggering can be effected from periodic signals in the range from dc to 5 megacycles, or from transients. This mode is especially useful with triggering signals that change slowly.

Another application of the DC triggering mode is to attain a stable display of a random-pulse train. The average voltage of this type of signal depends upon the duration of each pulse, the amplitude of each pulse, and the spacing between successive pulses. Therefore, the average voltage applied to the triggering circuits will fluctuate. This can result in unstable triggering if the **AC SLOW** or **AC FAST** mode is used. When the DC mode is used, however, the triggering circuits are sensitive to only the instantaneous applied voltage. Thus the sweep is initiated when any single pulse rises to a voltage selected by the **TRIGGERING LEVEL** control.

Operating instructions are similar to those given above for the **AC SLOW** mode, except that you set the red **TRIGGERING MODE** switch to **DC.**

AC Fast Mode

In the **AC FAST** mode, triggering can be effected from periodic signals in the range from 10 kilocycles to 5 megacycles. Characteristics are similar to those of the **AC SLOW** mode, except that low-frequency components of the triggering signal are rejected.

For most uses, the **AC SLOW** mode is preferable to **AC FAST. AC FAST** is principally for use with the Type 53/54C Dual-Trace Plug-In Unit (see below).

Aside from this use, **AC FAST** may reduce jitter due to hum in the triggering signal. Operating instructions are similar to those given above for the **AC SLOW** mode, except that you set the red **TRIGGERING MODE** knob to **AC FAST.**

Dual-Trace Operation, With Type 53/54C Plug-In Unit

This section describes use of the **ALTERNATE** sweeps mode of the Type 53/54C. For further information on use of the Type 53/54C, refer to the Instruction Manual for that unit.

In the present use, waveforms fed to **CHANNEL A** and to **CHANNEL B** connectors on the Type 53/54C are displayed alternately (see Fig. 13).

1. Select the desired triggering signal.
2. Set the Main Sweep **TIME/CM** switch for a sweep rate suited to the waveform being observed.
3. Set the control as follows:

HORIZONTAL DISPLAY	**MAIN SWEEP**
	NORMAL
TRIGGERING MODE	**AC FAST***
Main Sweep **TRIGGERING LEVEL**	full right or full left
Main Sweep **STABILITY**	**PRESET**†
MODE (on Type 53/54C)	**ALTERNATE**

4. Turn the Main Sweep **TRIGGERING LEVEL** control toward the 0 position for a stable display of the input signals. For further information on triggering in this mode see the Instruction Manual for the Type 53/54C.

*It may be preferable to use AC SLOW if one (or both) of the signals displayed is of low frequency.

†On instruments in Categories 1 and 2, set this control full right. Then turn it slowly to the left until the trace disappears; then two or three degrees farther left.

How to Use the Main Sweep Variable Stability Control

In instruments in Category 3, you might wish, in a few particularly difficult triggering applications, to use a setting of the Main Sweep **STABILITY** control other than the one available in the **PRESET** position. You can do this if you are using triggered operation in either the **AC SLOW**, the **AC FAST** or the **DC** mode.

1. Start with the Main Sweep **STABILITY** control turned full right. Use other control settings as given in the above instructions for the desired triggering mode.
2. Turn the Main Sweep **STABILITY** control left until the trace disappears, then two or three degrees further left.
3. Turn the Main Sweep **TRIGGERING LEVEL** control slowly toward the 0 position until the trace begins at the desired point on the waveform being observed
4. Set the Main Sweep **TIME/CM** switch for a sweep rate suited to the waveform being observed.

Type 54C. For further
the Type 53/54C, refer to
for that unit.

waveforms fed to CHAN-
NEL B connectors on the
ayed alternately (see Fig.

triggering signal.

ep TIME/CM switch for
d to the waveform being

follows:

MAIN SWEEP
NORMAL
AC FAST*

NG LEVEL full right or
full left
PRESET†
ALTERNATE

ep TRIGGERING LEVEL
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Sweep Variable Sta-

gory 3, you might wish,
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in Sweep STABILITY
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the desired point on
observed
TIME/CM switch for a
the waveform being

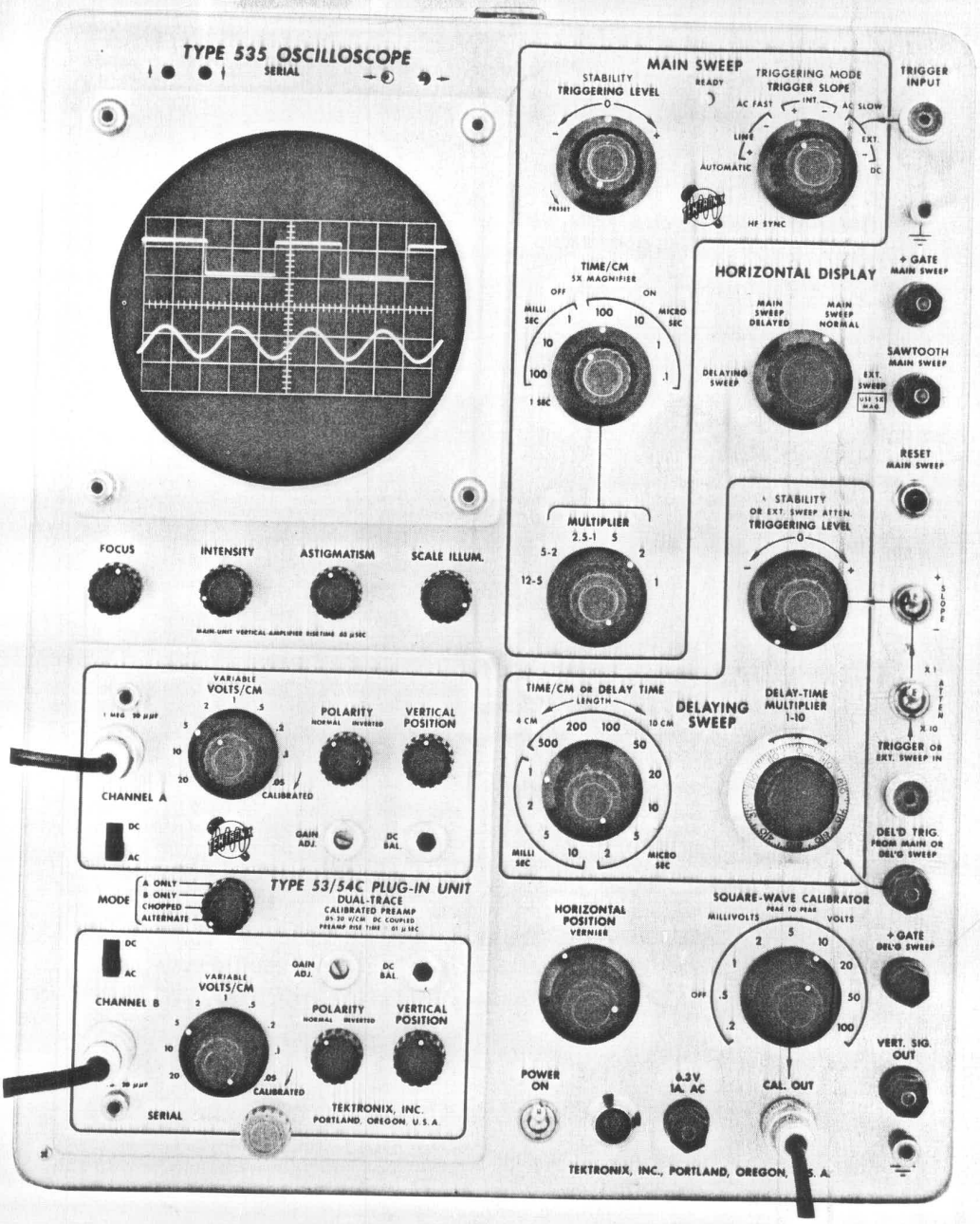

Fig. 13. Dual-Trace Operation

SYNCHRONIZED OPERATION

HF Sync Mode

When you use the **HF SYNC** mode, you get a recurrent horizontal sweep which can be synchronized, by means of the Main Sweep **STABILITY** control, with waveforms in the range from 5 megacycles to 15 megacycles.

When using the **HF SYNC** mode, you will usually want to synchronize the horizontal sweep with the waveform being displayed. To do this, set the controls as outlined in Step 1, at right. If, however, you want to synchronize the sweep with some external waveform, connect the source of this waveform to the **TRIGGER INPUT** connector and set the **TRIGGER SLOPE** knob to **+EXT.** or **—EXT.**

1. Set controls as follows:

HORIZONTAL DISPLAY	MAIN SWEEP NORMAL
TRIGGER SLOPE	+INT. or —INT.
TRIGGERING MODE	HF SYNC
Main Sweep **STABILITY**	full right

2. Set the Main Sweep **TIME/CM** switch for a sweep rate suited to the waveform being observed.
3. Turn the Main Sweep **STABILITY** control slowly to the left until you get a stable display of the waveform being observed.

FREE-RUNNING OPERATION

You can get a periodic, free-running sweep, independent of any external triggering or synchronizing signal.

As an application of free-running operation you can actuate the system under investigation by means of a signal from either the **+GATE MAIN SWEEP** or the **SAWTOOTH MAIN SWEEP** connector. (See "Output Waveforms" below.) The signals from these connectors have a starting time and a duration corresponding to the starting time and the duration of the horizontal sweep of the cathode-ray-tube spot. Note that this reverses the usual situation where the oscilloscope sweep is timed to the waveform under investigation. Here, the system being investigated is timed to the oscilloscope sweep. Thus a stable display is presented of the waveform resulting from actuating the system under investigation.

1. Use no input to the **TRIGGER INPUT** connector.
2. Set the controls as follows:

HORIZONTAL DISPLAY	MAIN SWEEP NORMAL
TRIGGER SLOPE	+INT., —INT., +EXT., or —EXT.
TRIGGERING MODE	AC SLOW or DC
Main Sweep **STABILITY**	full right
Main Sweep **TRIGGERING LEVEL**	full right or full left

3. Set the **TIME/CM** switch for a sweep rate suited to the waveform being observed.

Alternatively, you can get a free-running sweep at a fixed repetition rate of approximately 50 cycles, using the **AUTOMATIC** mode:

1. Use no input to the **TRIGGER INPUT** connector.
2. Set the controls as follows:

HORIZONTAL DISPLAY	MAIN SWEEP NORMAL
TRIGGER SLOPE	+INT., —INT., +EXT., or —EXT.
TRIGGERING MODE	AUTOMATIC*
Main Sweep **TRIGGERING LEVEL**	full right or full left

*On instruments in Category 1: Set the Main Sweep TIME/CM switch to 100 MICROSEC and the MULTIPLIER to 1. Set the TRIGGERING MODE control to AC AUTO. Turn the Main Sweep STABILITY control full right. Now slowly turn the Main Sweep STABILITY control to the left until the trace dims abruptly. Continue to turn the Main Sweep STABILITY control slowly left until the trace disappears. Now set the Main Sweep STABILITY control to a point halfway between the points where the trace dims and where the trace disappears.

lows:

MAIN SWEEP NORMAL

+INT.or —INT.

HF SYNC

full right

p TIME/CM switch for a to the waveform being

veep STABILITY control until you get a stable veform being observed.

NG LEVEL full right or full left

switch for a sweep rate eform being observed.

an ge. a free-running tition rate of approxi- the AUTOMATIC mode:

the TRIGGER INPUT

follows:

MAIN SWEEP NORMAL

+INT., —INT., +EXT., or —EXT.

AUTOMATIC*

G LEVEL full right or full left

ory 1: Set the Main Sweep ROSEC and the MULTIPLIER MODE control to AC AUTO. ITY control full right. Now STABILITY control to the ruptly. Continue to turn ontrol slowly left until the he Main Sweep STABILITY between the points where he trace disappears.

DELAYED TRIGGERS FROM MAIN SWEEP

Delayed positive-going triggering signals are available from the **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP** connector. You can use these triggering signals to actuate equipment external to the oscilloscope. When the **HORIZONTAL DISPLAY** switch is set to **MAIN SWEEP NORMAL**, these triggering signals appear after a predetermined delay time following the triggering of the Main Sweep. The duration of this delay time is equal to the product of the settings of the Main Sweep **TIME/CM** control, the **MULTIPLIER** control and the **DELAY-TIME MULTIPLIER** control.

DELAYING SWEEP

How to Select the Triggering Signal

It is always necessary, when you are using the Delaying Sweep, to supply a suitable triggering signal to the **TRIGGER OR EXT. SWEEP IN** connector. If you want to trigger the Delaying Sweep from the waveform being observed, you can connect a lead from the **VERT. SIG. OUT** connector to the **TRIGGER OR EXT. SWEEP IN** connector. (In this case, set the **ATTEN** toggle switch to **X1**.)

If you want the Delaying Sweep to start at a time when the triggering signal is rising (has a positive slope), set the **SLOPE** toggle switch to +. If you want the Delaying Sweep to start when the triggering signal is falling (has a negative slope), set the **SLOPE** toggle switch to —.

Set the **ATTEN** toggle switch to **X10** if the triggering signal exceeds about 10 volts.

How to Obtain a Delayed Sweep

1. Select the Delaying Sweep triggering signal as described above.

2. Set the controls as follows:

HORIZONTAL DISPLAY	DELAYING SWEEP
5X MAGNIFIER	OFF

Main Sweep controls:

TRIGGERING MODE	AC SLOW or DC
TRIGGER SLOPE	+EXT. or —EXT.
STABILITY	full right
TRIGGERING LEVEL	full right or full left

Delaying Sweep controls:

STABILITY	full right
TRIGGERING LEVEL	full right or full left
LENGTH	full right

3. Set the Delaying Sweep **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control so that the product of their settings is equal to the desired delay time between the triggering of the Delaying Sweep and the beginning of the display to be presented by means of the Main Sweep.

4. Set the Main Sweep **TIME/CM** and **MULTIPLIER** controls for a sweep rate suited to the waveform being observed. This rate is typically faster than that for which you set the Delaying Sweep **TIME/CM DELAY TIME** control.

When the waveform to be displayed is periodic:

Connect the source of signal to be displayed to the **INPUT** or **CHANNEL** connector. If the **INTENSITY** control is sufficiently advanced, you should see an unstable presentation of the displayed waveform. Turn the Delaying Sweep **STABILITY** control slowly to the left until the display disappears, then two or three degrees farther to the left. Then turn the Delaying Sweep **TRIGGERING LEVEL** control slowly toward 0 until the trace begins at the desired point on the Delaying Sweep triggering signal. If the **INTENSITY** control is set correctly, you should see a brightened portion of the trace. The length of this brightened portion is controlled by means of the Main Sweep **TIME/CM** and **MULTIPLIER**

controls, and the position of this brightened portion is controlled by means of the **DELAY-TIME MULTIPLIER** control. When you turn the **HORIZONTAL DISPLAY** control to **MAIN SWEEP DELAYED**, the brightened portion is displayed across the entire graticule length.

If you set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP** and then turn the **LENGTH** control to the left until the trace ends just after the brightened portion of the display, you can improve the duty factor and therefore the average brightness of the display presented when you turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP'DELAYED.**

When the waveform to be displayed occurs only once:

After completing Step 4 above, adjust the Delaying Sweep **STABILITY** and **TRIGGERING LEVEL** controls so that the Delaying Sweep will trigger at the desired point on the Delaying Sweep triggering signal. (You might want to display the **CALIBRATOR** waveform by means of the Delaying Sweep in making these adjustments.) Then connect the source of signal to be displayed to the **INPUT** or **CHANNEL** connector. Now turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED.** The Main Sweep is held "locked out" or inoperative until a predetermined delay time has elapsed after the triggering of the Delaying Sweep. This delay time is equal to the product of the settings of the **TIME/CM OR DELAY TIME** control and the **DELAY TIME MULTIPLIER** control. After this delay time has elapsed, the Main Sweep presents a display of the waveform under observation.

Typical application No. 1

The operation described above under the heading "When the waveform to be displayed is periodic" provides a very versatile magnifier, so that you can accurately select the portion of the waveform to be magnified and the amount of magnification. The amount of magnification is determined by the ratio of the **TIME/CM OR DELAY TIME** setting to the product of the Main Sweep **TIME/CM** setting and the **MULTIPLIER** setting.

Using this method, you can very accurately measure the time interval between two displayed events. Observe the magnified display with the **HORIZONTAL DISPLAY** switch in the **MAIN SWEEP DELAYED** position. Find the difference between the **DELAY-TIME MULTIPLIER** settings that successively place the two events directly under a given graticule line. Multiply this difference by the Main Sweep **TIME/CM** setting and by the **MULTIPLIER** setting. The result is the time difference between the two events.

Typical application No. 2

The operation described above under the heading "When the waveform to be displayed occurs only once" allows you to photograph any part of a transient waveform occurring at any desired time after the Delaying Sweep is triggered. For example, you can arrange to initiate an experimental action by operating an external push-button. Let the impulse from this push-button also trigger the Delaying Sweep. Then the Main Sweep will display a selected part of the resulting waveform occurring after a predetermined delay time. The amount of delay is determined by the product of the **TIME/CM OR DELAY TIME** setting and the **DELAY-TIME MULTIPLIER** setting. The duration of the display is chosen by setting the Main Sweep **TIME/CM** control and the **MULTIPLIER** control.

How to Obtain Delayed-and-Triggered Sweeps

1. Select the Main Sweep triggering signal as described under the heading "Main Sweep."
2. Set the Main Sweep **TIME/CM** and **MULTIPLIER** controls for a sweep rate suited to the waveform being observed. (This rate is typically faster than that for which you will set the Delaying Sweep **TIME/CM OR DELAY TIME** control, as described in Step 6.)
3. For most uses, if your instrument is in either Category 2 or Category 3, you can set the **TRIGGER SLOPE** switch to **+INT.** or **—INT.**, and set the **TRIGGERING MODE** switch to **AUTOMATIC.*** (Alternatively, on instruments in any category, you can use the Main Sweep **TRIGGERING MODE** switch in either the **AC SLOW** or the DC position, rather than **AUTOMATIC.** To do this, set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP NORMAL**, and set the **TRIGGERING MODE**, Main Sweep **TRIGGERING LEVEL** and Main Sweep **STABILITY** controls for triggering at the desired

*On instruments in Category 1, you can set the TRIGGERING MODE switch to AC AUTO. Then turn the HORIZONTAL DISPLAY switch to MAIN SWEEP NORMAL and adjust the Main Sweep controls for a stable display of the waveform you want to observe, as previously described.

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point on the triggering signal, as described under the heading "Main Sweep.")

4. Turn the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP**. Select the Delaying Sweep triggering signal as previously described.
5. Set the Delaying Sweep **STABILITY** and **LENGTH** controls full right. Set the Delaying Sweep **TRIGGERING LEVEL** control full right or full left.
6. Set the Delaying Sweep **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control so that the product of their settings is the amount of delay time you want to elapse between the triggering of the Delaying Sweep and the time when the Main Sweep becomes susceptible to triggering.

When the waveform to be displayed is periodic:

Connect the source of signal to be displayed to the **INPUT** or **CHANNEL** connector. If the **INTENSITY** control is sufficiently advanced, you should see an unstable presentation of the displayed waveform. Turn the Delaying Sweep **STABILITY** control slowly to the left until the trace disappears, then two or three degrees farther to the left. Then turn the Delaying Sweep **TRIGGERING LEVEL** control slowly toward the 0 position until the trace begins at the desired point on the Delaying Sweep triggering signal. If the **INTENSITY** control is set correctly, you should see a brightened portion of the trace. This brightened portion starts with the first Main Sweep triggering signal received after that point on the graticule determined by the **DELAY-TIME MULTIPLIER** setting. In other words, the brightened portion starts with the first Main Sweep triggering signal received after (1) the Delaying Sweep has been triggered and also after (2) the horizontal motion of the trace caused by the Delaying Sweep has gone on for a "delay" time equal to the product of the **TIME/CM OR DELAY TIME** setting and the **DELAY-TIME MULTIPLIER** setting. The length of the brightened portion is controlled by the Main Sweep **TIME/CM** and **MULTIPLIER** controls. When you turn the **HORIZONTAL DISPLAY** control to **MAIN SWEEP DELAYED**, the brightened portion is displayed across the entire graticule length.

When the waveform to be displayed occurs only once:

After completing Step 6 above, adjust the Delaying Sweep **STABILITY** and **TRIGGERING LEVEL** controls so that the Delaying Sweep will trigger at the desired point on the Delaying Sweep triggering signal. (You might want to display the **CALIBRATOR** waveform by means of the Delaying Sweep in making these adjustments.) Then connect the source of signal to be displayed to the **INPUT** or **CHANNEL** connector. Now turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED**. The Main Sweep is held "locked out" or inoperative until a predetermined delay time has elapsed after the triggering of the Delaying Sweep. This delay time is equal to the product of the settings of the **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control. After this delay time has elapsed, the first succeeding Main Sweep triggering signal that arrives will cause the Main Sweep to present a single display of the waveform under observation.

Delayed Triggers from Delaying Sweep

Delayed positive-going triggering signals are available from the **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP** connector. You can use these triggering signals to actuate equipment external to the oscilloscope. When the **HORIZONTAL DISPLAY** switch is set to **DELAYING SWEEP** or to **MAIN SWEEP DELAYED**, these triggering signals appear after a predetermined delay time following the triggering of the Delaying Sweep. The duration of this delay time is equal to the product of the settings of the **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control.

SINGLE SWEEPS

Manual Operation

1. Set the controls as follows:

HORIZONTAL DISPLAY	MAIN SWEEP DELAYED*

*With operation as described here, no delaying action is applied to the sweep.

Main Sweep controls:

TRIGGERING MODE	AC SLOW
STABILITY	full right
TRIGGERING LEVEL	full right or full left

Delaying Sweep controls:

STABILITY full left

2. Set the **TIME/CM** switch for a sweep rate suited to the waveform being observed.
3. Push the **RESET** button. You should get a single trace across the screen, displaying the waveform applied to the **INPUT** or **CHANNEL** connector.

Typical application No. 1

This operation is useful in photographing recurrent phenomena when succeeding waves are similar but not necessarily identical—for example, in certain biological work. After you have made the adjustments as given above, prepare your camera to receive the picture. Open the camera shutter, and immediately push the **RESET** button once; then close the camera shutter. The resulting picture will show a typical waveform, without blurring from succeeding waveforms that may not be exactly identical to the waveform photographed.

Typical application No. 2

You can use the manual single-sweep operation to photograph the result of an action which is initiated when you operate the **RESET** push-button. First make the adjustments described in Steps 1, 2 and 3 above. Connect the **+GATE MAIN SWEEP** connector to controlling circuits for the action to be initiated. (This connector supplies a positive-going rectangular waveform of about 30 volts amplitude starting when the **RESET** push-button is operated and the horizontal sweep begins.) Prepare your camera to receive the picture. See also separate Publication **FIP-3** "Notes on Practical Photography of Oscilloscope Displays," available from Tektronix. Connect the output of the transducer or other signal source to the **INPUT** or **CHANNEL** connector. Open the camera shutter and immediately push the **RESET** push-button once; then close the camera shutter. The resulting picture will show the response of the transducer to the desired action.

Triggered Operation

1. Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP NORMAL**, and turn the Delaying Sweep **STABILITY** control full left.
2. Set the Main Sweep **TIME/CM** control for a rate suited to the waveform being observed.
3. Adjust the Main Sweep controls for triggering on the desired triggering signal according to the **AC SLOW** or the **DC** mode as previously described.
4. Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED.** (With operation as described here, no delaying action is applied to the sweep.) Operate the **RESET** push-button. The **READY** lamp should now be lighted.
5. Connect the source of the expected signal to the **INPUT** or **CHANNEL** connector.
6. When the triggering signal is received, a single sweep will occur. Following this, the **READY** lamp will be extinguished. An additional single sweep will occur each time
   (A) the **RESET** push-button is operated and
   (B) following this, a triggering signal is received.

Typical application

This operation is useful in photographing a phenomenon that can occur at an unknown time or at a time when the operator is absent. After making the adjustments described in Steps 1 through 5 above, prepare your camera to receive the picture. Make sure that the **READY** lamp is lighted. Open the camera shutter. When the **READY** lamp is extinguished, close the camera shutter. (If any triggering signals are received after the first, they will not cause additional traces on the oscilloscope screen, so that your picture is protected against further exposures.) See also separate Publication **FIP-3**, "Notes on Practical Photography of Oscilloscope Displays," available from Tektronix.

5X MAGNIFIER

To expand a particular part of the display horizontally, first use the **HORIZONTAL POSITION** control to position that part of the display so that it falls near the vertical center line of the graticule. Then turn the **5X MAGNIFIER** switch to **ON**. That part of the display which occupied the middle two centimeters of the graticule will now be expanded to fill the graticule horizontally. Each major graticule division will now have a time value one-fifth of the value indicated by the **TIME/CM** switch.

EXTERNAL SWEEP

You might need to effect horizontal deflection of the spot across the screen by means of some externally derived waveform, rather than by means of the Main Sweep or the Delaying Sweep. To accomplish this, connect the source of this waveform to the **TRIGGER OR EXT. SWEEP IN** connector. Turn the **HORIZONTAL DISPLAY** switch to **EXT. SWEEP**, and turn the **5X MAGNIFIER ON**. Set the **STABILITY OR EXT. SWEEP ATTEN.** knob for the desired amount of horizontal deflection.

If you are using an externally derived sine wave for horizontal deflection, and if the frequency of this sine wave exceeds 240 kilocycles, you will have to limit the amount of horizontal deflection in order to avoid distortion of the display due to overloading of the horizontal-deflection system.

OUTPUT WAVEFORMS

A sawtooth waveform is available at the **SAWTOOTH MAIN SWEEP** connector on the front panel. This positive-going waveform starts at about zero volts and rises linearly to a peak amplitude of about 150 volts. The start of the rising part of the sawtooth is determined in the same way as the start of the Main Sweep. That is, the rising part of the sawtooth can be initiated by a triggering or synchronizing signal applied to the Main Sweep (see "Triggered Operation" or "Synchronized Operation"). Or the sawtooth can be generated in a periodic, free-running manner, without regard to any triggering or synchronizing signal (see "Free-Running Operation"). The rate at which the sawtooth rises is controlled by the Main Sweep **TIME/CM** and **MULTIPLIER** controls. The duration of the positive portion of the waveform corresponds to the duration of the left-to-right trace of the Main Sweep.

A rectangular waveform is available at the **+GATE MAIN SWEEP** connector on the front panel. This waveform starts at zero volts and rises to a peak amplitude of about 30 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the sawtooth available at the **SAWTOOTH MAIN SWEEP** connector discussed above.

A rectangular waveform is available at the **+GATE DEL'G SWEEP** connector on the front panel. This waveform starts at zero volts and rises to a peak amplitude of about 20 volts. Its starting time is determined in the same way as the start of the Delaying Sweep. That is, the positive part of the waveform can be initiated by a triggering signal to the Delaying Sweep when the Delaying Sweep **STABILITY** and **TRIGGERING LEVEL** controls are adjusted for triggered operation of the Delaying Sweep. Or the rectangular waveform can be generated in a periodic, free-running manner, without regard to any triggering signal if the Delaying Sweep **STABILITY** control is turned full right. The duration of the positive portion of the waveform corresponds to the duration of the left-to-right trace of the Delaying Sweep.

For information on the triggering signals available at the **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP** connector, see sections on "Delayed triggers from Main Sweep" and "Delayed triggers from Delaying Sweep."

RATE-GENERATOR FEATURE

While you are using the Main Sweep to display a waveform from some source, you can at the same time use the Delaying Sweep to perform these two simultaneous functions:

1. To actuate or trigger the source of the waveform being displayed.
2. To trigger the Main Sweep so that the display will be stable.*

The steps in this operation are as follows:

1. Turn the Delaying Sweep **STABILITY** control full right. Set the Delaying Sweep repetition rate to the desired value. In general, when the Delaying Sweep **LENGTH** control is turned full right, this repetition rate in cycles per

*This arrangement corresponds to that which is often called a "synchroscope."

second will be one-tenth the reciprocal of the setting in seconds of the **TIME/CM** or **DELAY TIME** control. You can make a precise determination of the repetition rate as follows:

a. Connect the probe cable to the **INPUT** or **CHANNEL** connector of the plug-in preamplifier, and connect the probe tip to the **+GATE DEL'G SWEEP** connector.

b. Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP NORMAL.** Set the Main Sweep controls to display the **+GATE DEL'G SWEEP** waveform (using the **AUTOMATIC** or the **AC SLOW** mode, as described previously under "Main Sweep—Triggered Operation".)

c. The repetition rate of the **+GATE DEL'G SWEEP** waveform is equal to the reciprocal of the product of the settings of the Main Sweep **TIME/CM** and **MULTIPLIER** controls and the horizontal distance in centimeters on the graticule occupied by one cycle of the waveform. The Delaying Sweep **LENGTH** control provides a fine control of the repetition rate.

2. Disconnect the probe tip from the **+GATE DEL'G SWEEP** connector. Connect the **+GATE DEL'G SWEEP** connector to the Main Sweep **TRIGGER IN** connector. Also connect the **+GATE DEL'G SWEEP** connector so that the leading edge of its output will trigger or actuate the source of the waveform to be observed.

(Note: Alternatively, you can use the output from the **DEL'D TRIGGER FROM MAIN OR DEL'G SWEEP** connector to actuate the source of the waveform to be observed. In this case the source of the waveform to be observed will be actuated **after** the Main Sweep is triggered. The delay time involved will be equal to the product of the settings of the **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control.)

3. Feed the waveform to be observed into the **INPUT** or **CHANNEL** connector of the plug-in preamplifier.

4. Set the Main Sweep **TRIGGER SLOPE** control to **+EXT.** Set the Main Sweep **TRIGGERING MODE, STABILITY** and **TRIGGERING LEVEL** controls for triggering in the **AC SLOW** or in the **AUTOMATIC** mode as described previously under "Main Sweep — Triggered Operation." If the repetition rate is greater than about 60 cycles per second, the **AUTOMATIC** mode will generally be satisfactory.

SUPERPOSITION OF WAVEFORMS

This operation is useful when you want to compare the first waveform in a recurrent wave train with a later waveform in the train.

1. Connect the **VERT. SIG. OUT** connector to the Delaying Sweep **TRIGGER OR EXT. SWEEP IN** connector. Connect a capacitor of about 100 $\mu\mu$f capacitance between the **+GATE DEL'G SWEEP** connector and the **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP** connector.

2. Set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP.** Connect the source of the wave train to the **INPUT** or **CHANNEL** connector of the plug-in preamplifier. Adjust the controls according to instructions given previously under the heading "How to Obtain a Delayed Sweep." Turn the **DELAY-TIME MULTIPLIER** control to a setting in the upper part of its range. Adjust the Delaying Sweep **TIME/CM OR DELAY TIME** control so that the desired number of waveforms is displayed.

3. You should now observe two brightened portions of the display—one at the start of the display at the left-hand end of the graticule, and the other at a later point along the graticule. Set the Main Sweep **TIME/CM** and **MULTIPLIER** controls so that the left-hand brightened portion includes the first waveform in the train. With the **DELAY-TIME MULTIPLIER,** move the second brightened area so that it includes the waveform you want to compare with the first waveform in the train.

4. Set the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED.** The display should now present both the first waveform in the train and the other waveform that was brightened in the preceding step. You can now use the **DELAY-TIME MULTIPLIER** to superimpose these two waveforms for precise comparison. The resulting reading of the **DELAY-TIME MULTIPLIER,** multiplied by the **TIME/CM OR DELAY TIME** setting, indicates the delay time between the waveforms

being compared. You can also now observe any jitter in the second waveform with respect to the first.
(Note: For the above method to function, there must be a time interval between the end of the first waveform and the beginning of the waveform being compared with the first waveform. Depending upon the **TIME/CM OR DELAY TIME** setting, this interval must be at least 10 to 20 microseconds.)

PHASE-ANGLE MEASUREMENTS

This operation is useful in determining the phase displacement between two identical waveforms of the same frequency (for example, two sine waves). The useful frequency range is from a few cycles to about 5 megacycles. For frequencies in the range from 1 to 5 megacycles, the effective resolution of the readings is reduced by a factor of 5. Use the Type 53/54C (or Type 53C) Plug-In Preamplifier.

1. Connect the source of the reference waveform to the **CHANNEL A** connector of the plug-in preamplifier and to the Main Sweep **TRIGGER INPUT** connector.

2. Set the oscilloscope controls as follows:

HORIZONTAL DISPLAY	**MAIN SWEEP NORMAL**
5X MAGNIFIER	**OFF***
Main Sweep controls:	
TRIGGERING MODE	**AC SLOW†**
TRIGGER SLOPE	**—EXT**
TRIGGERING LEVEL	full right or full left
STABILITY	**PRESET‡**
Delaying Sweep controls:	
STABILITY	full left
Plug-In preamplifier controls:	
MODE	**A ONLY**
AC-DC switches	both at **AC** or both at **DC†**
NORMAL-INVERTED switches	both at **NORMAL**

*For frequencies in the range from 1 to 5 megacycles, turn the 5X MAGNIFIER ON.
†For low-frequency waveforms, use the DC position.
‡For oscilloscopes in Categories 1 and 2, turn the STABILITY control full right.

3. On instruments in Categories 1 and 2, turn the Main Sweep **STABILITY** control slowly to the left until the trace disappears, then two or three degrees farther to the left.

4. Turn the Main Sweep **TRIGGERING LEVEL** control slowly toward 0 until you get a stable display of the reference waveform. Set the Main Sweep **TIME/CM** control so that this display includes several cycles of the waveform.

5. Using the **CHANNEL A VERTICAL POSITION** control, keep the trace centered vertically while you adjust the **CHANNEL A VOLTS/CM** and **VARIABLE** controls so that the peak-to-peak vertical deflection caused by the reference waveform is precisely 6 centimeters in the case of the Type 535, or precisely 4 centimeters in the case of the Type 545.

6. Keeping the display centered vertically adjust the Main Sweep **TRIGGERING LEVEL** control so that the start (left-hand end) of the displayed waveform appears precisely at the horizontal center-line of the graticule. With the **HORIZONTAL POSITION** control, position the left-hand end of the waveform precisely to the left-hand vertical graticule line. Set the Main Sweep **TIME/CM** black **MULTIPLIER** and red variable **MULTIPLIER** controls so that the display includes precisely 1 cycle of the wave-form displayed over the 10-centimeter graticule length. In succeeding steps, don't retouch the Main Sweep or Channel A controls.

7. Apply the second waveform to the **CHANNEL B** connector. Turn the **MODE** switch of the plug-in preamplifier to **B ONLY**. You should now see a stable display of the second waveform. Using the **CHANNEL B VERTICAL POSITION** control, keep the trace centered vertically while you adjust the **CHANNEL B VOLTS/CM** and **VARIABLE** controls so that the peak-to-peak vertical deflection caused by the waveform is precisely 6 centimeters in the case of the Type 535, or precisely 4 centimeters in the case of the Type 545.

8. Turn the **MODE** control on the plug-in preamplifier to **ALTERNATE**. You should now see a stable display that includes both the reference waveform and the second waveform whose phase relation you want to measure with respect to the reference waveform.

9. Locate the **CRT CATHODE** connector on the back of the oscilloscope. Disconnect the

jumper between the **CRT CATHODE** connector and the **GND** connector.
Then:

a. If the Main Sweep rate is faster than about 10 microseconds per centimeter, connect a test lead from the **CRT CATHODE** connector to the **DEL'D TRIG. FROM MAIN** or **DEL'G SWEEP** connector;

or

b. If the Main Sweep rate is slower than about 10 microseconds per centimeter, connect a test lead from the **CRT CATHODE** connector to the **+GATE DEL'G SWEEP** connector. Connect the **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP** connector to the Delaying Sweep **TRIG. OR EXT. SWEEP IN** connector. Turn the **TIME/CM OR DELAY TIME** control for a Delaying Sweep rate roughly 10 times as fast as the Main Sweep rate (unless the Main Sweep rate is so fast as to prevent such a setting; in the later case, set the **TIME/CM OR DELAY TIME** control to **2 MICROSEC.**). Turn the Delaying Sweep **STABILITY** control full right, and turn the Delaying Sweep **TRIGGERING LEVEL** control full left. Turn the **INTENSITY** control slowly toward the left until the trace brightness is at a minimum useful value. Slowly turn the Delaying Sweep **STABILITY** control to the left until the trace just disappears or abruptly dims. Turn the **INTENSITY** control slowly to the right until the trace just reappears or abruptly brightens. Slowly turn the Delaying Sweep **TRIGGERING LEVEL** control to the right until a stable blanked-out portion appears in the display.

10. A portion of each of the displayed waveforms should now be blanked out, and you should be able to position this blanked-out portion horizontally by means of the **DELAY-TIME MULTIPLIER** control. Position the start (left-hand end) of the blanked-out portion of the display precisely to the point where the reference waveform crosses the horizontal center-line of the graticule, and record the setting of the **DELAY-TIME MULTIPLIER** control. Position the start of the blanked-out portion of the display precisely to the point where the other waveform crosses the horizontal center-line of the graticule, and record the new setting of the **DELAY-TIME MULTIPLIER.** If the **5X MAGNIFIER** has been turned **OFF** during the preceding operations, multiply the difference between the two **DELAY-TIME MULTIPLIER** settings by 36 degrees. If the **5X MACNIFIER** has been turned **ON** during the preceding operations (for frequencies between 1 and 5 megacycles), multiply the difference between the two **DELAY-TIME MULTIPLIER** settings by 180 degrees. The result in either case is the phase difference between the two displayed waveforms.

Always replace the jumper between the **CRT CATHODE** and **GND** connectors when you have completed your measurements. This maintains the initial part at its normal brightness on fast sweeps.

JITTER REDUCTION

Suppose we want to display a waveform having either or both of these characteristics:

1. The desired waveform has appreciable amplitude jitter—that is, there is present, in addition to the desired waveform, a periodic waveform of lower frequency.
2. The frequency of the desired waveform jitters at a periodic rate lower than the frequency of the desired waveform.

If a source of the jitter signal alone is available (for example, if the jitter signal is the power-line waveform), you can markedly decrease or often almost eliminate the jitter in the display by the following operation.

1. Apply the source of jitter signal to the **TRIGGER OR EXT. SWEEP IN** connector. (If the jitter signal is the power-line waveform, you can use the **6.3V 1A. AC** connector as the source of jitter signal.) Set the **HORIZONTAL DISPLAY** switch to **DELAYING SWEEP**. Apply the jitter signal to the **INPUT** or **CHANNEL** connector. Turn the **VOLTS/CM** control and the **TIME/CM OR DELAY TIME** control to settings suited to the jitter signal. Adjust the Delaying Sweep **STABILITY** and **TRIGGERING LEVEL** controls for a stable display of the jitter signal. Now turn the **TIME/CM OR DELAY TIME** control to **2 MICROSEC**, and turn the **DELAY-TIME MULTIPLIER** to 1.0.

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2. Apply the desired signal, in place of the jitter signal, to the **INPUT** or **CHANNEL** connector. Leave the jitter signal connected to the **TRIGGER OR EXT. SWEEP IN** connector. Turn the **HORIZONTAL DISPLAY** switch to **MAIN SWEEP DELAYED**. Turn the **VOLTS/CM** control and the Main Sweep **TIME/CM** and **MULTIPLIER** controls to settings suited to the desired signal. Select the Main Sweep triggering signal (for example +INT. or —INT.), and adjust the Main Sweep for triggering in the **AC SLOW** or **AC FAST** mode.

The resulting display should be comparatively jitter-free.

VERTICAL-DEFLECTION SYSTEM

INPUT COUPLING

It is sometimes neither necessary nor desirable to display the dc component of the input waveform. A capacitor placed in series with the **INPUT** or **CHANNEL** connector, will block this dc component, but at the same time, will allow the ac component to be displayed. This is done when the **INPUT SELECTOR** switch or the **AC-DC** switch on the plug-in preamplifier is placed in the **AC** position.

DEFLECTION FACTOR

The **VOLTS/CM** switch controls the vertical deflection factor in accurately calibrated steps. The **VARIABLE** control provides fine adjustment of the deflection factor.

NOTE: To make the deflection factor equal to that indicated by the VOLTS/CM switch, set the VARIABLE control to the CALIBRATED position.

CONNECTING THE OSCILLOSCOPE TO THE SIGNAL SOURCE

Here are some precautions you should observe in connecting your oscilloscope to the source of signals to be displayed, or to a source of triggering signals.

1. Avoid errors in readings due to stray electric or magnetic coupling between circuits, particularly in the lead connected to the **INPUT** connector. In general, unshielded leads of appreciable length are unsuited to this use. This is true even in the audio-frequency range, except possibly when making measurements on low-impedance circuits at very low frequencies. When shielded leads are used, the shields should be grounded to the oscilloscope chassis and to the chassis of the equipment being tested. Coaxial cables are recommended for many purposes.

2. In broadband applications, it might be necessary to terminate a coaxial cable with a resistor or an attenuating pad presenting a resistance equal to the characteristic impedance of the cable. This is to prevent resonance effects or ringing (high-frequency damped oscillation). It becomes more necessary to terminate the cable properly as the length of the cable is increased. The termination is generally placed at the oscilloscope end of the cable, although many sources require an additional termination at the source end of the cable as well. Refer to the Accessories section of your Tektronix catalog for a listing of cables, terminating resistors and pads.

3. As nearly as possible, simulate actual operating conditions in the equipment being tested. For example, the equipment should work into a load impedance equal to that which it will see in actual use.

4. Consider the effect of loading upon the signal source due to the input circuit of the oscilloscope. The input circuit can be represented by a resistance shunted by a capacitance. Effective values of resistance and capacitance are indicated on the preamplifier panel. You should remember, however, that with a few feet of cable in the input circuit the loading capacitance on the circuit under investigation might be as high as 100 micromicrofarads or more. In some cases, the effects of these resistive and capacitive loads are not negligible, and to minimize them, you might want to use a probe in the manner described in the next section.

USE OF PROBES

An attenuator probe lessens both capacitive and resistive loading, at the same time reducing sensitivity. The attenuation introduced by the probe permits measurement of signal voltages in excess of those that can be accommodated by the preamplifier alone. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe (marked on probe).

The probe furnished with the oscilloscope has an attenuation ratio of 10 to 1. The maximum voltage that may be applied to the probe is 600 volts. Voltages in excess of this value (either dc volts or peak ac volts) may cause damage to components inside the probe body.

To preserve the waveform of the signal being displayed, it is generally necessary to clip the probe lead to the chassis of the equipment being tested. Select a ground point near the probe-input connection.

Before using the probe, always check its adjustment

An adjustable capacitor in the probe body compensates for variations in input capacitance from one instrument to another. To insure accuracy in pulse and transient measurements, check this adjustment frequently. To make this adjustment, set the **CALIBRATOR** controls for a calibrator output signal of suitable amplitude. Touch the probe tip to the oscilloscope **CAL. OUT** connector and adjust the oscilloscope controls to display several cycles of the waveform. Adjust the probe capacitor for a flat top on the calibrator square wave, as shown in the right-hand picture of Fig. 14.

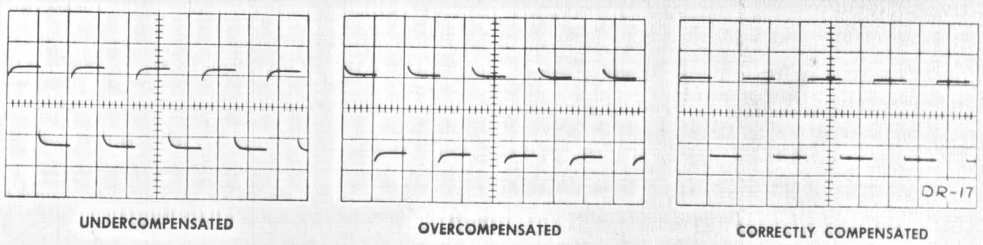

Fig. 14. Probe adjustments.

VOLTAGE MEASUREMENTS

We describe here two categories of voltage measurements with the oscilloscope: (1) measurement of the peak-to-peak voltage of a displayed waveform and (2) measurement of the peak voltage of a waveform with respect to a reference voltage. The specific examples that follow are intended to show the general procedure. These examples can be modified to suit any particular application.

How to Measure Peak-to-Peak Voltages

Suppose a given waveform produces the trace shown in Fig. 15 when a 10X probe is used and when the controls are set as follows:

AC-DC or INPUT SELECTOR	AC
VOLTS/CM	.1
VARIABLE	CALIBRATED

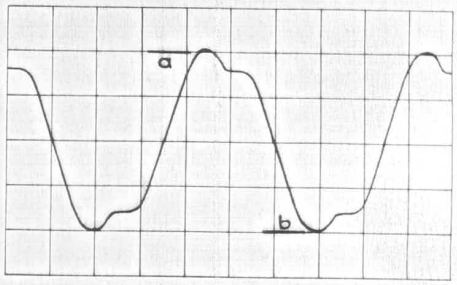

Fig. 15. How to measure peak-to-peak voltages.

The first step in measuring the peak-to-peak voltage of this waveform is to measure the amount of vertical deflection. The vertical dis-

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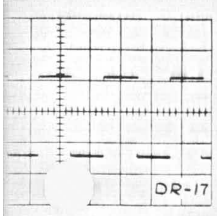
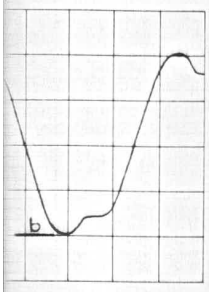


ECTLY COMPENSATED



peak-to-peak volt-

ing the peak-to-peak
is to measure the
on. The vertical dis-

tance from point *a*, the positive peak, to point *b*, the negative peak, is 4 centimeters. Multiply this figure by the **VOLTS/CM** setting, .1, and the result is .4 volt. This figure represents the voltage present at the **INPUT** or **CHANNEL** connector of the oscilloscope. Multiply this result by 10—the attenuation ratio of the probe. This gives 4 volts as the peak-to-peak voltage of the displayed waveform.

How to Measure a Peak Waveform Voltage With Respect to Ground

Set the **AC-DC** or **INPUT SELECTOR** switch to **DC**, and set the **VARIABLE** control to **CALIBRATED**. Adjust the oscilloscope for a free-running trace. Touch the probe tip to the oscilloscope ground terminal. Use the **VERTICAL POSITION** control to set the trace to a convenient position, such as *b* in Fig. 16. Next, disconnect the probe tip from ground terminal and connect it to the waveform source without disturbing the **VERTICAL POSITION** control. Adjust the oscilloscope controls for a stable display. Observe the vertical distance between the peak waveform voltage *a* and the original trace position *b*. If this distance is inconveniently large or small, reset the **VOLTS/CM** switch to a more suitable position and repeat the above procedure.

As an example, suppose the vertical distance between *a* and *b* is 4 centimeters when a 10X

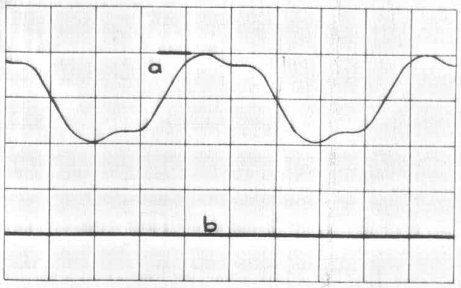


Fig. 16. How to measure a peak waveform voltage with respect to ground.

probe is used and when the **VOLTS/CM** switch is set at .1. Multiply the distance between *a* and *b* (4 cm.) by the **VOLTS/CM** setting (.1 v/cm.) and by the probe attenuation ratio (10). This shows the peak voltage of the waveform with respect to ground to be 4 volts.

In measuring signal amplitudes, it is important to remember that the width of the trace may be an appreciable part of the over-all measurement. This is particularly true when you are measuring signals of small amplitude or when stray-signal pickup has broadened the trace. Notice in Fig. 16 that points *a* and *b* correspond to the bottom side of the trace. The measurement would be just as accurate if points *a* and *b* correspond to the top side of the trace or to its center.

AUXILIARY FUNCTIONS

Calibrator

A primary use of the voltage **CALIBRATOR** is to provide a signal for checking the calibration of the vertical-deflection system, and for adjusting probes.

The **CALIBRATOR** provides a source of square waves of known amplitude at 1000 cycles ± about 30%. The output impedance varies with output-voltage setting, but is as high as 5,000 ohms. Be sure the load impedance you connect to the **CAL. OUT** connector is not so low as to change the output voltage.

Trace-Brightness Modulation

To couple markers or other signals into the crt cathode for trace-brightness modulation, disconnect the ground strap at the rear of the instrument and apply the signal between the **CRT CATHODE** binding post and **GND**.

Always replace the ground strap when you are not using this feature. This maintains the initial part of the trace at its normal brightness on fast sweeps.

Graticule Illumination

The graticule lighting control, labeled **SCALE ILLUM.**, can be adjusted to suit the lighting conditions of the room. The graticule can be mounted in either of two positions, rotated 180 de-

grees from each other. In one position the illumination is colored red and, in the other position, white. The white will reproduce well photographically.

A green light filter is supplied which can be used for increased contrast. Normally this filter should be mounted next to the crt screen so it does not block the light from the graticule lines.

Direct Connection to CRT Vertical-Deflection Plates

The two pins on the left-hand side of the crt neck are for connections to the vertical-deflection plates. A plastic plate and mounting bracket are available for making direct connections to the crt vertical-deflection plates. The mounting bracket is designed to clamp around the neck of the crt shield, adjacent to the deflection-plate connections. This plate is then accessible through the crt-deflection-plate access opening in the left-hand side-panel. To order this plate, specify Part No. 013-006 for oscilloscopes having serial numbers below 5001. Specify Part No. 013-007 for oscilloscopes having serial numbers 5001 and up.

If you wish to devise your own system of connections to the vertical-deflection plates, you can get an unwired plastic plate and mounting bracket by ordering Part No. 013-008 (for oscilloscopes having serial numbers 5001 and up, only). You can drill holes in the plate for mounting coaxial connectors or other components. Unless dc coupling is required, connect coupling capacitors in series with the leads to the vertical-deflection plates, and connect 1-megohm resistors from the vertical-deflection plates to the leads from the delay line. With these connections, the plates are maintained at their proper operating potential, and vertical-positioning control is retained for the front-panel **VERTICAL POSITION** control. If you use another method of connections, maintain the average dc potential on the vertical-deflection plates at +300 volts to avoid distortion. If you use a different potential, you can minimize the distortion by readjusting the internal GEOM. ADJ. control at the rear of the sweep chassis.

OPERATING DESCRIPTIONS OF CONTROLS AND CONNECTORS

HORIZONTAL DISPLAY — Four-position switch. In the **MAIN SWEEP NORMAL** and the **MAIN SWEEP DELAYED** positions, the output of the Main Sweep is connected to the sweep-amplifier input. In the **DELAYING SWEEP** position, the output of the Delaying Sweep is connected to the sweep-amplifier input. (In the **MAIN SWEEP DELAYED** and the **DELAYING SWEEP** positions, the Main Sweep is held inoperative—"locked out"—until after a delay time following triggering of the Delaying Sweep. See **DELAY-TIME MULTIPLIER**, p. 38.) In the **EXT. SWEEP** position, the **TRIGGER OR EXT. SWEEP IN** connector is connected to the sweep-amplifier input. (When the **HORIZONTAL DISPLAY** switch is in the **EXT. SWEEP** position, the **5X MAGNIFIER** switch should be turned **ON**.)

Main Sweep TRIGGER SLOPE — Black **TRIGGER SLOPE** switch selects Main Sweep triggering signal — the signal being displayed (+**INT.** or —**INT.**), some signal fed into the **TRIGGER INPUT** connector (+**EXT.** or —**EXT.**), or the power-line wave (+**LINE** or —**LINE**). In the +**INT.**, +**EXT.** and +**LINE** positions, triggering occurs during the voltage rise of the triggering waveform. In the —**INT.**, —**EXT.** and —**LINE** positions, triggering occurs during the voltage fall of the triggering waveform.

Main Sweep TRIGGERING MODE — Five-position switch (red knob) selects one of four types of triggering (**AUTOMATIC, AC SLOW, DC** or **AC FAST**), or synchronized operation (**HF SYNC**). See discussions of these operating modes on pp. 21-22.

Main Sweep STABILITY — Red **STABILITY** control adjusts the Main Sweep for triggered or for free-running operation. When the Main Sweep **TRIGGERING MODE** switch is in the **AC SLOW, DC** or **AC FAST** position, the Main Sweep **STABILITY** control can generally be used in its **PRESET** position. (For manual operation of the Main Sweep **STABILITY** control, see p. 22.) This control serves as the synchronizing control when the **TRIGGERING MODE** switch is in the **HF SYNC** position. The Main

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Sweep **STABILITY** control is disabled when the Main Sweep **TRIGGERING MODE** switch is in the **AUTOMATIC** position.

Main Sweep **TRIGGERING LEVEL** — Black **TRIGGERING LEVEL** control determines at what voltage on the input triggering signal the horizontal trace will start. This control is disabled when the Main Sweep **TRIGGERING MODE** switch is in the **AUTOMATIC** or **HF SYNC** positions.

Main Sweep **TIME/CM** — Eight-position switch (black knob) to control Main Sweep rate.

MULTIPLIER — Six-position switch (black knob). Three positions, marked in black, indicate factors by which **TIME/CM** settings are to be multiplied to obtain Main Sweep rate. Three positions, marked in red, provide continuously variable (uncalibrated) Main Sweep rate control by means of associated red knob.

TRIGGER INPUT — Coaxial connector for accepting an external triggering signal for the Main Sweep generator when the Main Sweep **TRIGGER SLOPE** switch is in the **+EXT.** or the **—EXT.** position.

TRIGGER OR EXT. SWEEP IN — Coaxial connector. When the **HORIZONTAL DISPLAY** switch is in the **EXT. SWEEP** position, this connector accepts external horizontal-deflection waveforms. In other positions of the **HORIZONTAL DISPLAY** switch, this connector accepts triggering signals for the Delaying Sweep. (See **ATTEN**, below.)

ATTEN. toggle sw. — Two-position switch. When waveforms supplied to the **TRIGGER OR EXT. SWEEP IN** control exceed about 10 volts, use the **X10** position. Otherwise, use the X1 position.

SAWTOOTH MAIN SWEEP — Connector supplying a positive-going sawtooth having a peak value of about +150 volts. The rising part of the sawtooth coincides with the left-to-right trace of the Main Sweep. The rate at which the sawtooth rises is controlled by the Main Sweep **TIME/CM** switch and by the black and red **MULTIPLIER** controls.

+GATE MAIN SWEEP — Connector supplying a positive-going rectangular wave having a maximum value of about +30 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the sawtooth available at the **SAWTOOTH MAIN SWEEP** connector.

RESET MAIN SWEEP — Push-button which produces manually-controlled single sweeps (p. 27), or which arms the Main Sweep for triggered single sweeps (p. 28).

Delaying Sweep **SLOPE** toggle sw. — Two-position switch. In the + position, triggering of the Delaying Sweep occurs during the voltage rise of the triggering waveform. In the — position, triggering of the Delaying Sweep occurs during the voltage fall of the triggering waveform.

STABILITY OR EXT. SWEEP ATTEN. — Red control adjusts the Delaying Sweep generator for triggered or free-running operation. When the **HORIZONTAL DISPLAY** switch is in the **EXT. SWEEP** position, it provides continuously adjustable control of sweep-amplifier gain.

Delaying Sweep **TRIGGERING LEVEL** — Black control determines at what voltage on the Delaying Sweep input triggering signal the Delaying Sweep will start.

Delaying Sweep **TIME/CM OR DELAY TIME**	Twelve-position switch to control Delaying Sweep rate. (See also **DELAY-TIME MULTIPLIER**, below.)
DELAY-TIME MULTIPLIER 1-10	Ten-turn control. When the **HORIZONTAL DISPLAY** switch is in the **DELAYING SWEEP** or the **MAIN SWEEP DELAYED** positions, the Main Sweep is held inoperative—"locked out"—until after a delay time following the triggering of the Delaying Sweep. This delay time is the product of the settings of the **TIME/CM OR DELAY TIME** control and of the **DELAY-TIME MULTIPLIER** control. (See also **DEL'D TRIG. FROM MAIN OR DEL'G SWEEP**, below.)
DEL'D TRIG FROM MAIN OR DEL'G SWEEP	Connector supplying delayed positve-going triggering signals. When the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP NORMAL** position, the output triggering signal occurs following the start of the Main Sweep, after a delay equal to the product of the settings of the Main Sweep **TIME/CM** control, the **MULTIPLIER** control and the **DELAY-TIME MULTIPLIER** control. When the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP DELAYED** or in the **DELAYING SWEEP** position, the output triggering signal occurs following the start of the Delaying Sweep, after a delay equal to the product of the settings of the **TIME/CM OR DELAY TIME** control and the **DELAY-TIME MULTIPLIER** control.
Delaying Sweep **LENGTH**	Sweep-length control permits delaying sweep to be reverted immediately after delayed main sweep is triggered, to increase possible duty factor. Normally will be set full right.
+GATE DEL'G SWEEP	Connector supplying a positive-going rectangular wave having a maximum value of about +30 volts. Its positive portion coincides with the left-to-right trace of the Delaying Sweep.
5X MAGNIFIER	When the red **5X MAGNIFIER** knob is turned from the **OFF** position to the **ON** position, that part of the display which occupied the middle two divisions of the graticule is expanded to fill the graticule horizontally. Turn the **5X MAGNIFIER ON** when you set the **HORIZONTAL DISPLAY** switch to **EXT. SWEEP.**
HORIZONTAL POSITION	Black knob positions trace horizontally.
VERNIER	Red knob provides fine control of horizontal position of trace.
VERT. SIG. OUT	Supplies sample of waveform being displayed vertically on oscilloscope. About 2 volts peak-to-peak for each centimeter of vertical deflection.
SQUARE-WAVE CALIBRATOR	B'ack knob selects any one of nine calibrator square-wave output amplitudes. Red knob (three-position switch) selects whether black-knob reading is in volts or in millivolts; also turns calibrator **OFF.**
CAL. OUT	Coaxial connector for supplying square-wave output voltage from calibrator
6.3V 1A. AC	Connector supplying 6.3 volts ac at a maximum current of 1 ampere.
Beam-position indicators	Indicator lamps marked with arrows. The arrow nearest the illuminated indicator shows which way the beam is off the screen if it cannot be seen.
CRT CATHODE	Connector at rear of cabinet for accepting beam-intensity-modulation voltage. Capacitively coupled. This connector should be jumpered to the **GND** connector when not in use.

See **DELAY-TIME**

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VERTICAL POSITION (on plug-in unit)	Positions trace vertically.
VOLTS/CM (on plug-in unit)	Switch provides fixed calibrated vertical-deflection factors when the **VARIABLE VOLTS/CM** control is set to **CALIBRATED**.
VARIABLE VOLTS/CM (on plug-in unit)	Provides continuously variable (uncalibrated) vertical-deflection factors between those provided on the **VOLTS/CM** switch.
INPUT or **CHANNEL** (on plug-in unit)	Connector for accepting waveforms to be displayed vertically on the oscilloscope screen.

INDEX

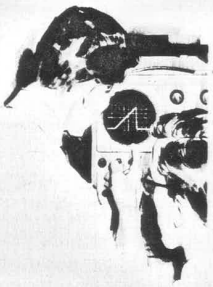
TEKTRONIX FIELD SERVICES

Tektronix Customers are urged to take advantage of the many field services available to them through Tektronix Field-Engineering Offices, Engineering Representatives, and Overseas Engineering Organizations. Some of these services are described below.

Ordering—There are many types of oscilloscopes, each designed for a specific application area. Your Field Engineer can help you select the one best suited to your present and future needs, and he will be happy to arrange a demonstration of the instrument.....in your application if you so desire.

If you are a Purchasing Agent or Buyer, your Field Engineer or his secretary can help you with information on prices, terms, shipping estimates, and best method of transportation on instruments, accessories, and replacement parts.

If you are responsible for the maintenance of a large quantity of Tektronix Instruments, ask your Field Engineer about the free factory training course in maintenance and calibration.

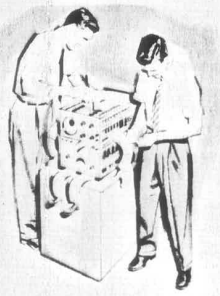


Applications—Perhaps the answers you need in a specific application can be obtained faster and easier through use of your Tektronix Oscilloscope. Your Field Engineer can help you find out, and if use of your oscilloscope is indicated, help you with procedures. He may also be able to suggest many time-saving uses for your oscilloscope in routine checks and measurements.

Operation—Your Tektronix Oscilloscope can be most useful to you when you are familiar with all control functions. Your Field Engineer will be glad to demonstrate the use of your instrument in various applications to help you become more familiar with its operation. If your instrument is to be used by several engineers, your Field Engineer will be happy to conduct informal classes on its operation in your laboratory.

Instrument Reconditioning—An older Tektronix Oscilloscope, properly reconditioned, can give you many additional years of service. Your Field Engineer will gladly explain the advantages and limitations of factory reconditioning, and make the necessary arrangements if you decide in favor of it.

Many major repair and recalibration jobs can be performed at a nearby Field Repair Station. Ask your Field Engineer about this at-cost service to Tektronix customers.



Maintenance—Tektronix willingly assumes much of the responsibility for continued efficient operation of the instruments it manufactures. If you should experience a stubborn maintenance problem, your Field Engineer will gladly help you isolate the cause. Often a telephone discussion with him will help you get your instrument back into operation with minimum delay. If yours is a large laboratory, your Field Engineer can be of service to your maintenance engineers by conducting informal classes on test and calibration procedures, trouble-shooting techniques, and general maintenance.

Communications—Your Field Engineer is a valuable communication link between you and the factory. He knows the exact person to contact in each circumstance, and he can reach that person fast and easily. Let him help speed your communications with the factory on any problem related to your Tektronix Instruments.

Tektronix, Inc.

Tektronix, Inc., P. O. Box 831, Portland 7, Oregon

Telephone: CYpress 2-2611 TWX—PD 311 Cable: TEKTRONIX

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Northern New Jersey served by:		
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